# NAVAL POSTGRADUATE SCHOOL
## Monterey, California


# THESIS

**A METHODOLOGY FOR COMPREHENSIVE QUANTITATIVE EVALUATION OF A COMPUTER AIDED EXERCISE USING THE JOINT THEATER LEVEL SIMULATION (JTLS)**

by

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Computer aided exercises (CAXs) are tools available for monitoring and training staffs in these tasks. A primary goal during a CAX is to present a realistic decision environment to the training audience in order to produce realistic results. This thesis develops an analysis methodology for using exercise data to evaluate critical event causal audit trails. Specific objectives are: 1) to develop methodologies to objectively analyze the causes for critical events, and 2) to demonstrate the effectiveness of these methodologies through the use of the Joint Theater Level Simulation (JTLS).

This thesis develops post-exercise analysis techniques for output data and provides a methodology for extracting appropriate data from a CAX. The results of a given CAX will then be more compatible with additional analysis techniques, such as trend analysis, and more useful and timely feedback can be provided to participants.

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# ABSTRACT

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AAW | Anti-Air Warfare |
| ASCM | Anti-Ship Cruise Missile |
| CAP | Combat Air Patrol |
| CAX | Computer Aided Exercise |
| CG | Guided Missile Cruiser |
| CINC | Commander-in-Chief |
| CJCS | Chairman, Joint Chiefs of Staff |
| CPX | Command Post Exercise |
| CRC | Coleman Research Corporation |
| CVBG | Carrier Battle Group |
| CVN | Aircraft Carrier, Nuclear |
| DCA | Defensive Counter Air |
| ESM | Electronic Support Measures |
| HVU | High Value Unit |
| JMETL | Joint Mission Essential Task List |
| JOA | Joint Operating Area |
| JTLS | Joint Theater Level Simulation |
| KKMC | King Khalid Military City |
| MEU | Marine Expeditionary Unit |
| MHE | Material Handling Equipment |

| | |
|---|---|
| MOE | Measures of Effectiveness |
| MOP | Measures of Performance |
| MOP | Memorandum of Policy |
| MSSG | Marine Supply Support Group |
| NEO | Noncombatant Evacuation Operations |
| OPM | On-line Player's Manual |
| R&A | Rolands and Associates Corporation |
| RDBMS | Relational Database Management System |
| ROE | Rules of Engagement |
| SAM | Surface-to-Air Missile |
| SQL | Structured Query Language |
| TM | Theater Missile |
| UJTL | Universal Joint Task List |
| WRR | Weapons Release Range |

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# EXECUTIVE SUMMARY

The Joint Training Program defined within the Chairman Joint Chiefs of Staff (CJCS) establishes a program for carrying out the joint training responsibilities of the CJCS, the Joint Commanders-in-Chief (CINCs), and the CINCs' component staffs. This program institutes a method for identifying training requirements through the review of the CINC's missions and the compilation of essential tasks required to accomplish those missions.

For consistency and comparability purposes, each CINC is required to develop a Joint Mission Essential Task List (JMETL) based on the missions and essential tasks outlined in the Universal Joint Task List (UJTL) document. The CINCs are responsible for identifying the joint tasks which are most crucial to their missions and which occur most frequently; and identifying which tasks are in the greatest need of training.

How does a CINC go about identifying which tasks are "in the greatest need of training?" One of the primary training tools available to the Commander-in-Chief (CINC) for training his staff on their joint mission essential tasks is a Computer Aided Exercise (CAX). Simply stated, the problem is that currently there is no comprehensive tool for a CINC to use to evaluate a CAX (during or after the wargame), accurately pinpoint critical events in any or all mission areas, then determine **why** these critical events occurred.

Critical events are those events of significance that singularly or in concert with a limited number of like events could cause operational and/or strategic level consequences. The question of why the critical event occurred is of great importance, and the vehicle for

ascertaining the answer is the *audit trail.* Audit trails are created by careful examination and manipulation of the simulation's post-processor output. The goal is to use the output to trace backward from the occurrence of a critical event in an attempt to discover the causal relationships.

In order to standardize the process of tracing a critical event's audit trail, one must have a consistent methodology that is applicable for any type of critical event. One method that will achieve these goals is a checklist of all reasonable scenario parameters that could affect an event. One should be able to reconstruct the ground, air and/or naval situation of interest at any historical time during a training event. Once general questions are posed and the relevant questions answered , the analyst can then, if necessary, move to the next step of generating a set of *critical event specific* queries.

This type of analysis can be done using various exercise support simulations, but the Joint Theater Level Simulation (JTLS) is best suited for this research. JTLS is an interactive, multi-sided, joint (air, land, sea, and special operations) and combined (coalition warfare) constructive simulation model which is used as both a robust tool to analyze theater level operations plans and as a vehicle to support training exercises and seminar wargames.

Rolands and Associates Corporation (R&A), the developer of JTLS, has created a set of routines which continually update ASCII output files with critical data during the conduct of a JTLS exercise. These files were developed in conjunction with the UJTL assessment effort and provide a variety of data describing engagement results, resupply,

and a number of other characteristics. The data are chronological and serve to assist in the identification of changes in the behavior of the units during critical events. In JTLS Version 2.1, the data can be loaded into a Structured Query Language (SQL) based relational database that can be queried by the analyst.

Through manipulation of this post-processor database one can begin to trace critical event audit trails derived from the following "Gulf War-like" scenario. Iraqi forces in this scenario have attacked across the border to Hafir-al -Batin in north central Saudi Arabia and to the Kuwaiti border along the coast. The immediate objective was to seize the Trans-Arab pipeline and control the flow of oil in northern Saudi Arabia.

Variations of three critical events were chosen for audit trail analysis: 1) the events surrounding the 2/24th Mechanized Infantry's failure to follow a retreating Iraqi Madinah division, portions of the same event as seen from an Iraqi perspective; 2) an Iraqi air strike on the Coalition port of Dahrahn; 3) an Iranian air strike on the Coalition Carrier Battle Group (CVBG), and a revisitation of the same event from an Iranian point of view.

Analysis showed that the Madinah Division's unimpeded withdrawal was due primarily to the lack of Coalition intelligence assets, which hindered the 2/24th Mech's efforts to locate Madinah. From the Iraqi perspective, the air strike on the 2/24th Mech was very successful because the Iraqi forces were provided with intelligence from armed reconnaissance missions seeking out the 2/24th Mech's location. The Dahrahn air strike was a Coalition failure due to an experimental design that did not utilize Coalition air forces or air defense capabilities in the wargame scenario. The Coalition CVBG was

devastated by Iranian air forces because Coalition Combat Air Patrol (CAP) was eliminated early in the scenario. From the Iranian perspective, extensive and unopposed patrol aircraft provided CVBG position intelligence enabling accurate and efficient air strikes.

Analysis was also performed on a similar scenario that was played out with heavy gamer interaction. The resulting "parallel" critical events provided different causal audit trails. In this case, the Madinah division was defeated due to: 1) the Coalition forces' ability to constantly track the Madinah's location, and 2) the aggressive tactics of the players involved. A parallel Iraqi air strike on the port of Dahrahn was very successful due to: 1) the players inability to properly create effective Combat Air Patrols, and 2) the limited number and capabilities of Dahrahn's organic air defense assets.

# I. INTRODUCTION

> It is far cheaper in the long run, and far safer, to pay the price that readiness requires - even in this safer world that our past efforts have made possible. [Ref. 1]

## A. BACKGROUND

In peacetime, military professionals must acquire the skills and develop the confidence and initiative necessary to conduct joint and combined operations. While professional schools are fundamentally important, the military is a hands-on profession and most learning at all levels is accomplished while participating in unit training and operations. Hence, realistic, demanding, and objectively measured training and exercises are essential. The Joint Training Program defined within the Chairman Joint Chiefs of Staff (CJCS) Memorandum of Policy 26 (MOP 26) establishes a program for carrying out the joint training responsibilities of the CJCS, the Joint Commanders-in-Chief (CINCs), and the CINCs' component staffs. MOP 26 institutes a method for identifying training requirements through the review of the CINC's mission and the compilation of essential tasks required to accomplish that mission. Each compiled task list is called the CINC's Joint Mission Essential Task List (JMETL).

A CINC's JMETL is intended to provide the basis for all joint training. A JMETL consists of those tasks deemed essential for accomplishment of operational plans; it is predicated on the missions assigned and forces apportioned to the CINC, U.S. alliances or treaties, or regional initiatives. A JMETL includes Joint Mission Essential Tasks, supporting tasks considered essential for accomplishment of the Joint Mission Essential Tasks, and enabling tasks.

The Universal Joint Task List (UJTL), a supplement to the Joint Training Manual (MCM 71-92), outlines a comprehensive list of joint essential tasks [Ref. 2]. As displayed in Figure 1, that document provides:

- a summary listing of CINC Missions.
- a list of Joint Tasks, the corresponding Supporting Tasks, and their Enabling Tasks.
- a detailed dictionary of the Joint Tasks, Supporting Tasks, and the Enabling Tasks, describing each task in detail.

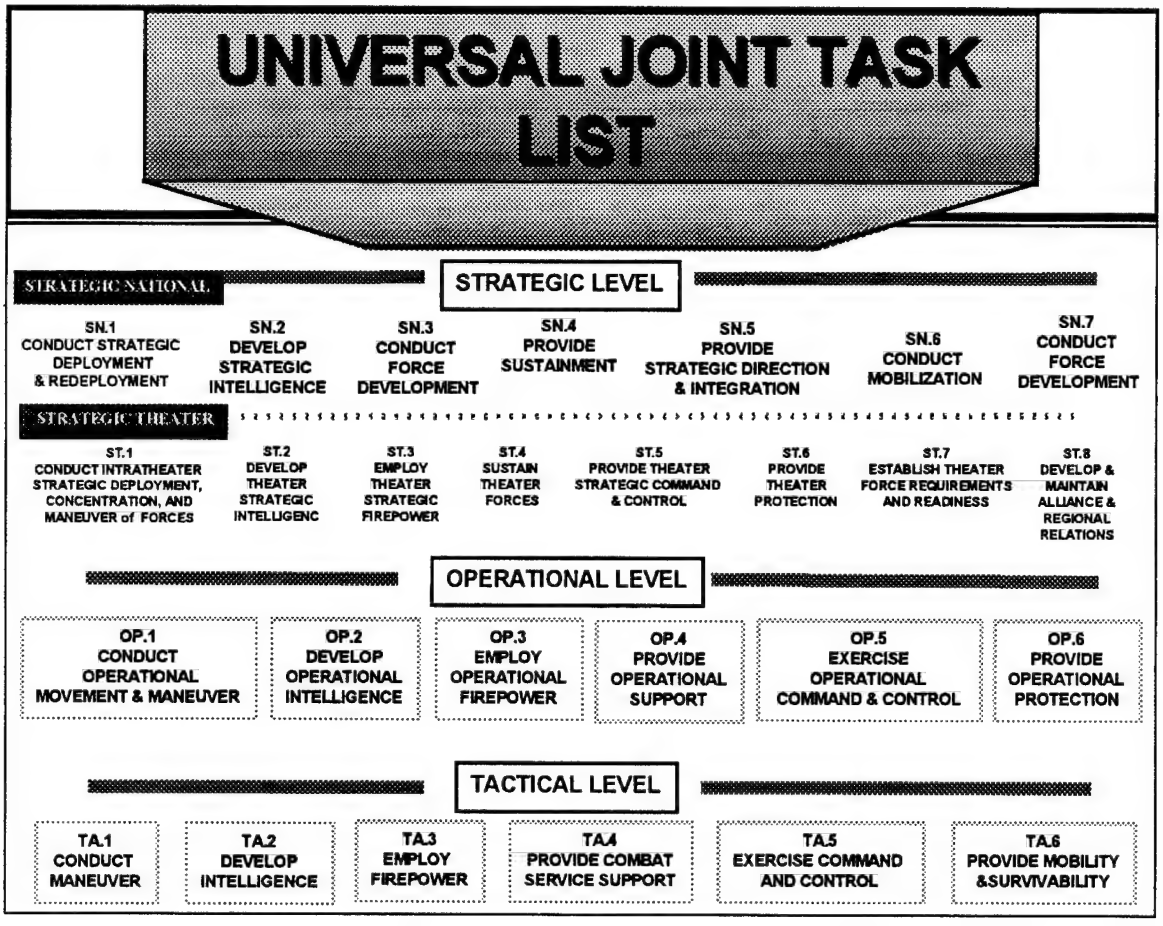



**Figure 1. Universal Joint Task List Diagram.**

For consistency and comparability purposes, each CINC is required to develop a JMETL based on the missions and essential tasks outlined in the Universal Joint Task List document. The CINCs are responsible for identifying their major missions from the summary listing, mapping the major missions to the joint tasks, determining the joint tasks which are most crucial to their missions and which occur most frequently, and finally identifying which tasks are in the greatest need of training.

## B. PROBLEM STATEMENT

How does a CINC go about identifying which tasks are "in the greatest need of training?" In addition to subjective post-exercise commentary, a complementary, objective set of MOEs are needed to quantitatively evaluate staff performance in all potential Joint Mission Essential Tasks. One of the primary training tools available to a CINC for training and evaluating his staff in this regard is an exercise supported by a computer simulation model. This is commonly referred to as a Computer Aided Exercise (CAX). A primary goal during a CAX is to present a realistic decision environment to the training audience in order to produce realistic results.

Although CAXs have proved to be an essential training tool for a CINC and his staff, until recently there have been few methodologies available to quantitatively evaluate the results of the CAX in a manner that lends itself to be applied across **all** CAXs. It has been, at best, an ad-hoc process.

The research efforts of Combs [Ref. 3], Towery [Ref. 4], Brown [Ref. 5], Mustin [Ref. 6], Cwick [Ref. 7], Sullivan [Ref. 8], Thurman [Ref. 9], and Gordon [Ref. 10]

developed individual methodologies and measures of effectiveness (MOEs) to quantify and evaluate the performance of a CINC's staff in separate and distinct mission areas. These theses covered the topics of logistics support, intelligence functions, operational maneuver, carrier battle group anti-air warfare, amphibious logistics, mobilization planning, force protection, and operational firepower, respectively. Given these tools, a CINC can begin to identify reasons why an exercise produced a given outcome in a given mission area. These methodologies assist in locating critical events in a scenario that significantly contribute to its outcome. There still exists the problem of formulating comprehensive MOEs to evaluate his staff's overall performance in **all** mission areas.

Simply stated, the problem is that currently there is no comprehensive tool for a CINC to use to analyze a CAX (during or after a wargame), accurately pinpoint critical events in any or all mission areas, then determine **why** these critical events occurred. This thesis will provide analysts with that comprehensive tool.

## C. THESIS STRUCTURE

Chapter II describes the proposed analysis methodology used to assess staff performance. The presented methodology focuses on the analysis of significant events that occur during an exercise. Chapter III applies the methodology to a typical exercise scenario using JTLS. This chapter discusses the data manipulation necessary for post exercise analysis using an existing computer simulation, the background of the combat scenario used for this project, and the background of each selected critical event that will be audited. Chapter IV develops the actual causal audit trails for each example event.

Chapter V uses the same methodology to analyze the outcome of a JTLS version 2.1 demonstration scenario. Chapter VI summarizes the methodology and provides recommendations for further refinements and analysis.

# II. METHODOLOGY

> We owe the men and women who may be in harm's way every edge technology can provide. Technology will never be a substitute for courage or human toughness in conflict, but it can increase the likelihood that the tough and courageous will be successful. [Ref. 11]

## A. CRITICAL EVENTS

Critical events are those events of a momentous nature that singularly or in concert with a limited number of like events could cause operational and/or strategic level consequences. Some examples of events of this nature might be the defeat of a tank battalion, the destruction of a forward deployed ground unit, or the completion of a successful reconnaissance mission.

Given the stochastic nature of a CAX, it is possible for critical events to occur at any point in the scenario. Because a CAX is a training tool for the CINC, the question of why the critical event occurred is of great importance. The vehicle for ascertaining the answer is the *audit trail.* Audit trails are created by careful examination and manipulation of the simulation's post-processor output. The goal is to use the output to trace backward from the occurrence of a critical event in an attempt to discover the causal relationships.

Currently, the only capabilities investigators have in developing the audit trail are quantitative items such as the exact time, place and strength of a unit where the critical event occurred. If all logically required assets are present and functioning at the time of the critical event, then it might be said that the event occurred due to the stochastic nature of the model. This is the realism imparted by stochastic models. For example, a Patriot defense system may be on station; however, Scuds may still penetrate the air defense envelope. Any enemy threat for which adequate preparation has apparently been made

still has a positive probability of defeating the planned defense, regardless of the level of preparation. This type of critical event is well explained through audit trail analysis. The situation gets more difficult to evaluate when pieces seem to be missing from the puzzle. If, for instance, a major supply depot is destroyed by undetected enemy air forces and it is subsequently discovered, via the audit trail, that the depot was virtually unprotected, the CINC will want to know why.

The nature of combat is such that the most seemingly trivial events can eventually have significant ramifications. The smallest details in combat contribute to the occurrence of each event, and compounding these events leads to a cascading effect that may, in turn, become a critical event. It is beyond the scope of plausible audit trail analysis to consider every event of each battlefield entity, but it is possible for the true cause of a campaign's outcome to be masked by these details. The quantitative nature of current audit trail analysis makes it possible to answer the question of *why* various events took place only to a reasonable level of detail. In the context of the supply depot example above, the analyst may discover that there was an air defense unit which was not located close enough to the supply depot. The question of *why* the unit was not close enough to provide sufficient defense still remains, and this question can be answered only to the level of detail that the available data support.

## B. QUERY TEMPLATE

In order to standardize the process of tracing a critical event's audit trail, one must have a consistent methodology that is applicable for any definable type of critical event.

One method that will achieve these goals is a checklist of all reasonable scenario parameters that could affect an event. One should be able to reconstruct the ground, air and/or naval target situation at any historical time during a training event. By using the following checklist of general questions in the same manner for every possible critical event, the causal relationships may gradually become more evident, allowing for the next phase of the analysis.

- Time and location: When did the critical event occur, and what were the locations of all involved units and/or targets?
- Force strength: What are the force strengths of the participating units in the critical event? Are any reasonably too low? Do any of the participating units have key combat systems casualties?
- Environmental conditions: Did weather, visibility conditions, or terrain hamper or overly assist any participating units in accomplishing their given missions?
- Command and control issues: Were units on both sides able to communicate? Were any participating units given multiple tasking or possibly confusing orders?
- Logistics: Were there any supply shortfalls? Were they due to a lack of or a misallocation of assets?
- Intelligence: Were there any intelligence shortfalls? Were they due to a lack of or a misallocation of assets?
- Subjective issues: Did this critical event happen due to an unexplained miscalculations or an error in a commander's judgment, or due to chance?

Once these questions are posed and the relevant questions answered, the analyst can then, if necessary, move to the next step of generating a set of *critical event specific* queries, as exemplified in Chapters III, IV, and V.

# III. JTLS APPLICATION

## A. JOINT THEATER LEVEL SIMULATION (JTLS)

One of the factors involved in the development of a computer aided exercise is selection of the appropriate software model, or exercise driver. The selection of the model is often driven by the objectives of the training exercise. Each model has its own operating characteristics in terms of what can be represented, method of presentation, and level of detail and fidelity.

The Joint Theater Level Simulation is an interactive, multi-sided, joint (air, land, sea, and special operations) and combined (coalition warfare) constructive simulation model which is used as both a robust tool to analyze theater level operations plans and as a vehicle to support training exercises and seminar wargames. JTLS strives to model conflict at the operational level with tactical fidelity. Additionally, JTLS maintains a complete suite of documentation encompassing all functional areas and describing how they interact throughout the game. The following list of parameters describe the capabilities and limitations of JTLS [Ref. 12]:

**Span:** Defense Mapping Agency's nearly universal digitized maps and terrain data permit the model to be used worldwide. The Terrain Modification Unit (TMU), a JTLS software tool, can be used to built terrain files to support the JTLS model. Current map surface area is based on a Lambert conformal projection and, hence, constrained only by the lack of resolution that occurs with ranges larger than approximately 2000 NM on each side.

**Environment:** The terrain database for an exercise divides the area of operation into contiguous hexagons. JTLS aggregates the terrain within a hex in terms of environmental characteristics such as basic terrain type, trafficability, elevation, chemical or nuclear contamination and weather. Roads connect hex centers; railroads and pipelines are mapped via independent node to node networks; and rivers, shorelines and other impediments to movement (such as ditches) map to hex borders.

**Force Composition:** JTLS is designed for multi-sided coalition warfare with air, land, sea and special operations forces. It also models civilian and non-combatant forces within sectors of interest. Forces can be positioned on up to ten sides and divided into an unlimited number of factions on any side. Units can change factions during the game and factions can change sides. Side and faction names are user-configurable via the database.

**Scope of Conflict:** JTLS is a "big picture" wargame that focuses on conventional and coalition operations at the operational level of war. It supports limited nuclear and chemical effects, dynamic coalition development, designation of political or military factions, setting Rules of Engagement (ROE), executing Host-Nation Support agreements, conducting Noncombatant Evacuation Operations (NEO) and operational conflict.

The JTLS Combat Events Program (CEP) uses the SIMSCRIPT programming language to support the need for a discrete time simulation. Most of JTLS' interfaces and support tools programs are written in the C language. The advantage of discrete time simulation is the ability to model activities that potentially lead to critical events. The key processes of theater level conflict are most easily visualized as a collection of discrete

(key) events. The collection of these events takes time to occur and potentially change the state of systems.

Rolands and Associates Corporation, the developer of JTLS, has created a set of routines which continually update ASCII output files with critical data during the conduct of a JTLS exercise. These files have been developed in conjunction with the UJTL assessment effort and provide a variety of data describing engagement results, resupply, and a number of other characteristics. The JTLS JMET output files for a run of JTLS comprise the input to the relational database for subsequent data retrieval. JTLS version 2.1 employs the ORACLE Relational Database Management System (RDBMS).

## B. DATABASE MANAGEMENT SYSTEM FUNDAMENTALS

A successful database design incorporates user requirements of storing and retrieving data into a flexible architecture that allows for efficient execution and future modification. The end product becomes a self-describing collection of integrated records [Ref. 13].

Relational database designs require transformation of semantic objects to facilitate platform implementation. The formal definition explains the semantic object as a "named collection of attributes that sufficiently describes a distinct identity." [Ref. 14] Each attribute has a range of possible values called a domain. The domain may be numeric, string or enumerated. To this end, a relation, or two-dimensional table, containing data is developed from a semantic object. The semantic object model provides the most flexible approach to modeling new database applications. Not only is the model easier to develop,

it is more readily implemented on a variety of platforms. Also, in terms of "life cycle" design, a semantic model allows for rapid and easy future modification. Relational tables are defined by their columns; data are then stored as rows in the table. A sample table structure is shown in Figure 2.

By creating several tables of interrelated information, more complex and powerful operations may be performed. **The power of the database lies in the relationships that can be constructed between the pieces of information, rather than in the pieces of information themselves.**

Tables can be related to each other via three types of relationships: one-to-one, one-to-many, and many-to-many. In a (1:1) relationship, the tables share a common primary key. A primary key is the column or set of columns that makes each record in a table unique. Consider the ***fictional*** example of the **TANKS** table from Figure 2.

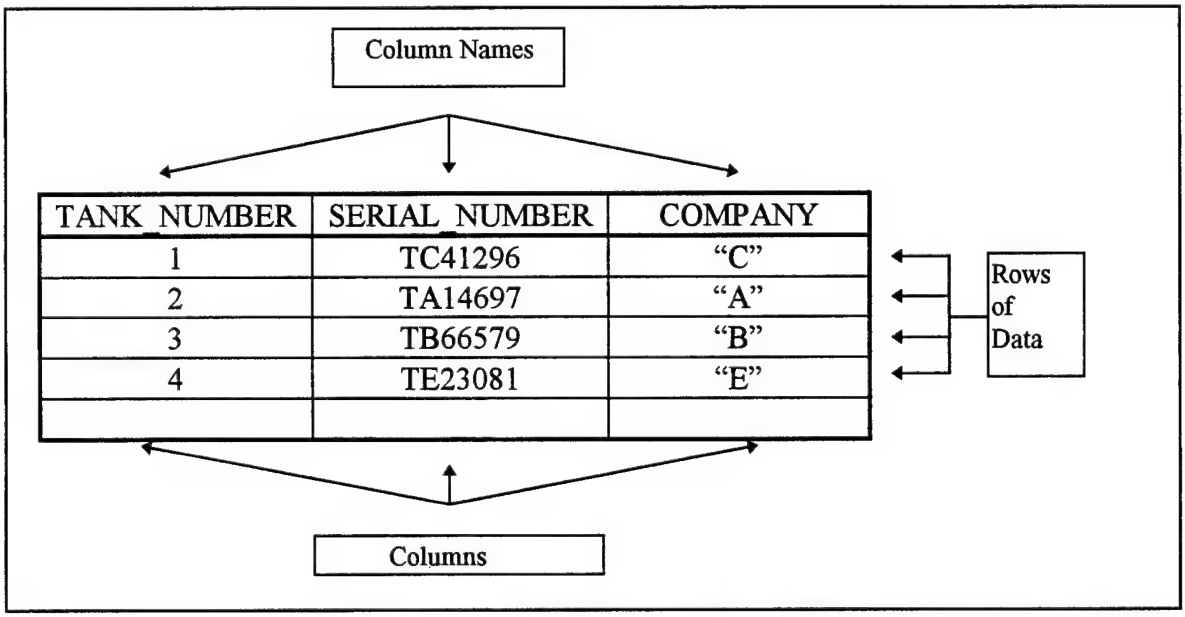



**Figure 2. Example of table structure.**

**TANKS** is the object being represented. TANK_NUMBER is the object identifier; it is a Key attribute that uniquely identifies an instance of the object. What if an additional column, **TIME_IN_SERVICE**, were to be added to the data being stored? Since each tank will have its own number indicating days in service, the **TIME_IN_SERVICE** column should be stored in the **TANKS** table. However, this will force the database to read through the entire data type value every time the table is queried, even if only the field containing the time information is being sought. To improve performance, a second table can be created, called **TANKS_TIME_IN_SERVICE**. This table will have the same primary key (**TANK_NUMBER**), and one additional column (**TIME_IN_SERVICE**). The two tables thus have a 1:1 relationship. This is shown graphically in Figure 3. The solid line between the two entities indicates the relationship is

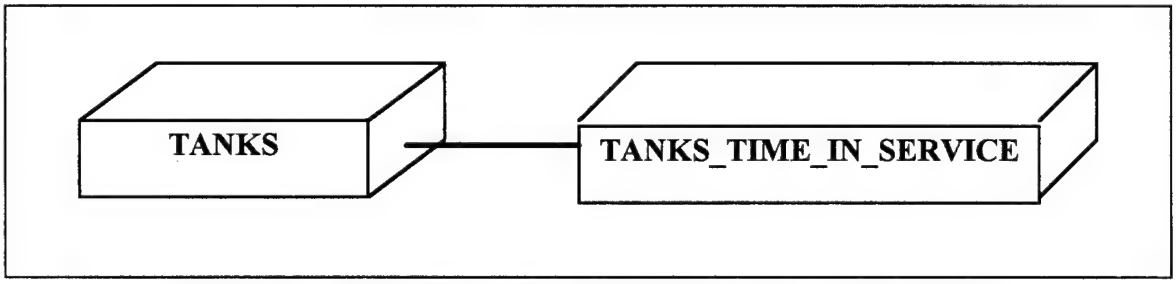



**Figure 3. Entity relationship diagram for a 1:1 relationship.**

mandatory. Had the relationship been optional, it would have been represented with a dashed line.

One-to-one relationships are rare. It is far more common for a relationship to be of the one-to-many variety. In this type of relationship, one record in one table is related to many records in another table. A foreign key is a set of columns that refers to an existing primary key. In the **TANKS** table shown in Figure 2, there is only one tank per

company. Obviously, multiple tanks are assigned to the same company. To facilitate this, a new entity, **COMPANY**, would be created. The **COMPANY** column of the **TANKS** table would then be a foreign key to this new table.

Since many tanks (records in the **TANKS** table) can be assigned to a single company (record in the **COMPANY** table), there is a 1:M relationship between these tables. This is shown graphically in Figure 4. Note two differences in the connecting line: the addition of a crow's-foot on the "many" side of the relationship, and the use of a dashed line on the "one" side. The dashed line is used to signify that the relation is not mandatory on that side (i.e., it is possible to have a company with no tanks assigned to it). Generally, the transformation of 1:M compound objects involves designating the object of one, as parent, and the object of many, as child. When we place the key attribute of the parent into the relation of the child, the child receives a foreign key from the parent.

It may also be possible that many rows of a table are related to many rows of another table. Considering the **TANKS** table, assume that tanks may be drawn from multiple motor pools. Conversely, a motor pool provides numerous tanks to units. Thus, there is a many-to-many relationship between the **TANKS** entity and the **MOTOR_POOLS** entity. To understand this relationship, note that a single tank could be drawn from many motor pools (records in the **MOTOR_POOLS** table), and that the

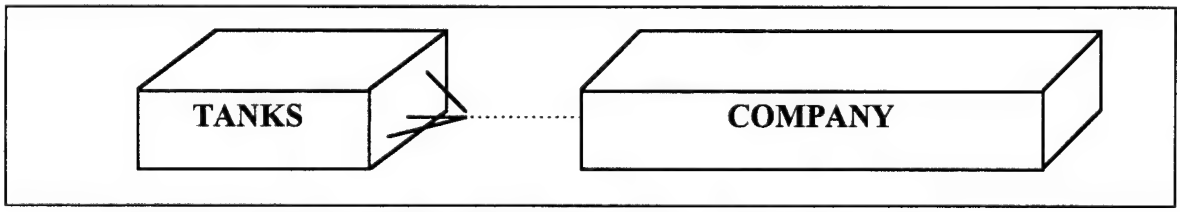



**Figure 4. Entity relationship diagram for a 1:M relationship.**

reverse is also true. This relationship is shown in Figure 5. Many-to-many relationships between two compound objects require three relations. One relation for each object and a third relation representing the intersection between the objects are developed for the transformation. This third relation takes the key attributes of each object. If there are additional data representing aspects of this relationship, then it is called an association object. Generally, transformation of association objects requires the same process as for compound objects. However, the child receives a foreign key from each parent in the association object case.

Structured Query Language (SQL) is the language used to retrieve data from the database by providing the ability to query multiple relations to extract relevant

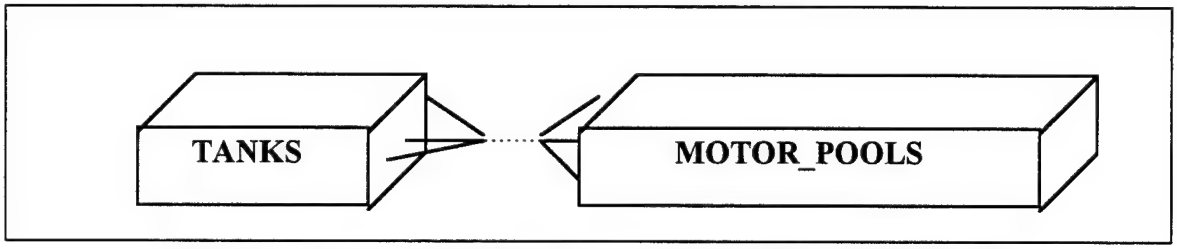



**Figure 5. Entity relationship diagram for a M:M relationship.**

information. Developed in the 1970s by IBM, it is the industry standard data manipulation language.

Relational algebra is the foundation for SQL implementation. Similar to algebra, relational algebra treats relations as variables. There are seven primary operations in relational algebra:

- The *union* of two relations adds the rows of the relations, forming a third relation.

- The *difference* between two relations produces a new relation with rows not in the original two.
- The *intersection* of two relations is a third relation of rows in both original relations.
- The *product* of two relations, one consisting of m rows and the other consisting of n rows, produces an m by n matrix relation.
- The *selection* operator identifies rows to be placed in a new relation.
- *Projection* places specified attributes from a relation into a new relation.
- The *join* operator brings together applications of the product, selection, and projection operations.

From the example in Figure 2, if asked to select the tank from the table **TANKS** where the serial number is TB66579, the correct response would be "tank number three." SQL code to perform the same query is: select **TANK_NUMBER** from **TANKS** where **SERIAL_NUMBER** = TB66579

The response would be:

**TANK_NUMBER**
---
**3**

This simple example serves only to emphasize the conceptual simplicity of queries using SQL. Queries developed for this analysis, however, draw upon the more sophisticated and significant SQL capabilities.

## C. POSTPROCESSOR CONSTRUCTION

The output data produced by JTLS 2.0 was in the form of JMET output files or "flat files." Each flat file was merely a collection of columns of data grouped under a collective data file name, as exemplified in the following format for the JTLS 2.0 engagement data flat file:

**engagement_data:**

| | |
|---|---|
| **TIME.V,** | time of the engagement |
| **TEXT.TYPE.ENGAGEMENT,** | air-to-air, surface-to-air, etc. |
| **SHOOTER.NAME,** | name of the shooting unit |
| **WEAPON.NAME,** | harpoon, stinger, etc. |
| **NBR.FIRED,** | the number of weapons fired |
| **TEXT.AIM.POINT,** | where the weapon will land |
| **REAL.LAT,** | latitude of the target |
| **REAL.LONG,** | longitude of the target |
| **TEXT.VICTIM.NAME,** | name of the unit whose target was hit |
| **TEXT.TYPE.OBJECT.DAMAGED,** | damaged target's type (e.g. SAM site) |
| **NAME.OBJECT.DAMAGED,** | SAM site #3, etc. |
| **AMOUNT.DAMAGED,** | percentage of target destroyed |
| **PROB.KILL,** | based on range, target, & weapon type |
| **ENGAGEMENT.RANGE** | range of weapons release |

The format of all JTLS 2.0 JMET output files can be seen in Appendix A. This format limits the analyst in that viewing data common to more than one flat file becomes a complicated process, necessitating data sorting and filtering algorithms. The efforts of Brown [Ref. 5] and Mustin [Ref. 6] exemplify the extensive efforts needed to transform these data into a usable format that both the analyst and the reader can understand. Their extensive use of Pascal sorting programs and Excel spreadsheets demonstrated that their analyses were definitely complicated processes.

With the implementation of JTLS version 2.1, wargame data are also output in the form of "flat files," but the content of these files is slightly augmented from its

predecessor. The biggest difference between versions 2.0 and 2.1 is the utilization of these files. JTLS 2.1 takes the data from the flat files and inputs into an ORACLE relational database. This database creates tables for each respective mission area of interest. The code used to produce these tables, available from the authors, shows the sources and methods used to create each table and the resulting structure of each created table. From theses tables, the associated ORACLE Reports software also enables graphics and presentation packages to be developed.

## D. SCENARIO REQUIREMENTS

The scenarios from which the data used in this thesis were developed were all set in the Southwest Asia theater of operations. The standard scenario allowed for the buildup of American forces in the region before any Iraqi incursion, typical of recent history. The variations were developed to establish conditions for successful development of the measures of performance in evaluating operational maneuver [Ref. 5], amphibious logistics [Ref. 7], operational firepower [Ref. 10], carrier battle group anti-air warfare capability [Ref. 6], joint mobilization plans [Ref. 8] , and force protection [Ref. 9]. A number of configurations were developed for the experimental runs of JTLS. These combinations are shown in Table 1. Three different starting scenarios were investigated. One provided for conditions which represented sufficient time for force buildup (Light). A variation on this scenario exhibited conditions of an enemy seizure of the strategic initiative, sufficiently degrading the ability to build combat power quickly in theater (Heavy). The second scenario required that long distances be covered to bring forces in

contact with the enemy. This provided for analysis of the ability, or inability, to create a temporal advantage in less than ideal conditions. The third scenario provided for conditions under which American Carrier Battle Group (CVBG) air defenses would be tested by attacks from Iranian air forces.

Within each of the first two starting scenarios, a run was conducted for situations where each side gained the *operational* advantage with respect to initiative. Certain key decisions were scripted to insure that one side or the other was able to exploit an advantage to demonstrate the effect on the measures of effectiveness dealing with the mission areas discussed in the previous paragraph.

| | Heavy Scenario: Initial Iraqi Incursion | Light Scenario: Iraq Postured on Border |
|---|---|---|
| Iraqi Initiative: | Run #1 | Run #3 |
| Coalition Initiative: | Run #2 | Run #4 |

| Naval Scenario: | Run #5 |
|---|---|

**Table 1. Experimental Run Conditions.**

## E. HEAVY SCENARIO

The heavy scenario was established to demonstrate the difficulty in generating combat power and establishing a temporal advantage. The Iraqi forces in this scenario have attacked across the border to Hafir-al -Batin in north central Saudi Arabia and to the Kuwaiti border along the coast. The immediate objective was to seize the Trans-Arab pipeline and control the flow of oil in northern Saudi Arabia. Force locations as Coalition forces begin to arrive in theater are shown in Figure 6.

The deployment sequence was formulated to allow for one brigade each from the 101st Airborne Division and 24th Mechanized Infantry Division to arrive without difficulty at a port city near the city of Dhahran. Because the database already contained United Kingdom forces in the region, they were used to support Saudi Arabian forces in the vicinity of King Khalid Military City (KKMC). Finally, the Iraqi advance along the coast stopped short of crossing into Saudi Arabia, allowing the deployment of two Marine

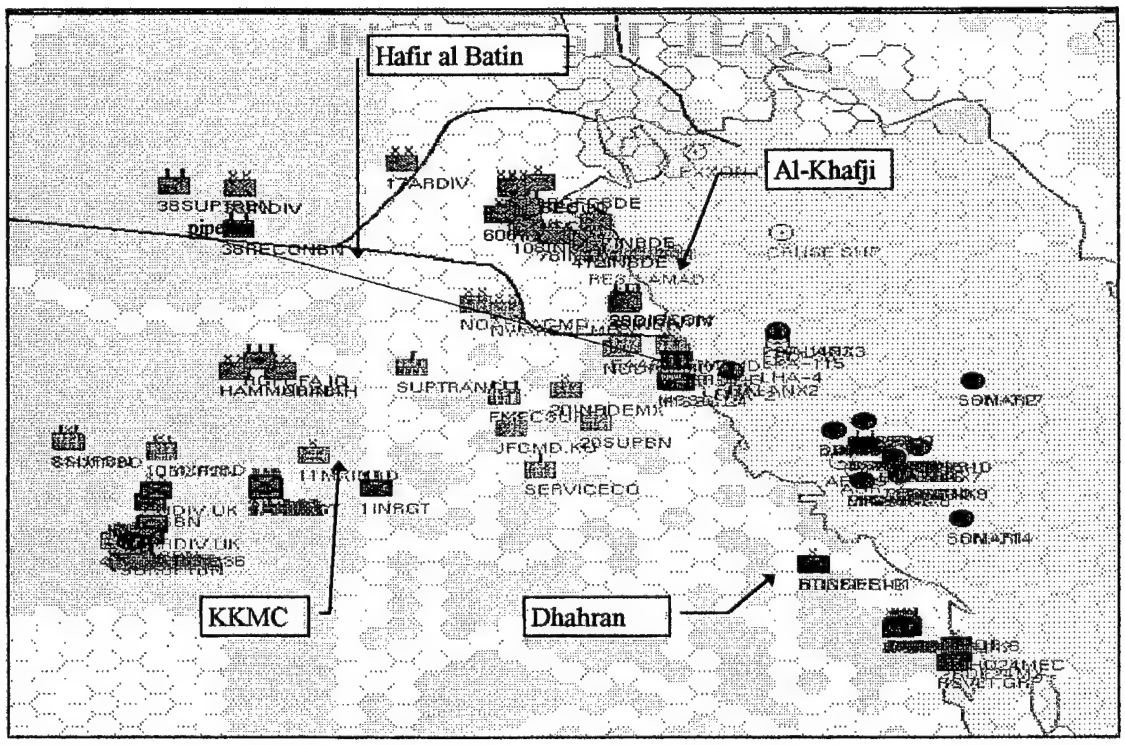



**Figure 6. Initial Force Locations at Start of Run #1 and Run #2.**

Expeditionary Units into the area of Al-Khafji.

### 1. Run #1: Heavy Scenario, Iraqi Initiative

This scenario was developed devoid of Coalition intelligence, air defense, and air missions, thereby hampering the operations of the Coalition force. This scenario is

designed to evaluate the Coalition response to a large Iraqi initiative *without* a large massing of Coalition forces on the Iraqi border.

The conditions exhibited were of an enemy seizure of the strategic initiative, sufficiently degrading the ability of Coalition forces to build combat power quickly in theater. The scenario was designed so that long distances had to be covered to bring forces in contact with the enemy. This added to the difficulty in generating combat power and establishing a temporal advantage.

Under the conditions of Iraqi strategic initiative, forces attacked well in advance of any Allied presence in the region. Iraqi forces secured the operational initiative by conducting preemptive air strikes on deploying United States forces. Forces from the 2nd Brigade of the 24th Mechanized Infantry Division (2/24th Mech) were given the mission to move west and support the defense of KKMC. The Iraqi air and ground efforts were designed to impede that movement.

One hour into the game the 2/24$^{th}$ Mech and 3$^{rd}$ Brigade of the 101$^{st}$ Airborne Division (3/101 ABD ) arrived and were joined by their subordinate units. The 2/24th Mech began moving toward KKMC, and the 3/101 ABD began to move towards Khafji in the north. The 2/24 Mech was slowed by Iraqi air strikes as it moved west.

Coalition forces arrived into theater unhampered until 1400 on Day One, when the port at Dhahran was hit with an aerial attack. This caused units arriving through this port to be processed slower than usual for the next 12 hours because of the damage to the port's Material Handling Equipment (MHE). A queue built up as units waited at the port

to be processed. As MHE was repaired, units waiting were processed according to their priority assigned in the Time Phase Force Deployment Data (TPFDD).

Shortly into Day Two, the Iraqi 17th Armor Division began to withdraw after an engagement with Coalition forces left them severely damaged. Two other significant events occurred on the second day. One was closure of the 1st Brigade of the 101st Airborne Division (1/101 ABD ) and 1st Brigade of the 24th Mechanized Infantry Division (1/24th Mech) and their movement toward Khafji and KKMC, respectively. The other was an Iraqi attack on the USMC units in the east. By midday, enough Coalition units had arrived to begin counterattacks in the west region north of KKMC and in the east region near Khafji.

By the beginning of Day Three, Iraqi forces in both the east and west regions had been damaged to the point where they began to withdraw. By midday, Coalition forces had pushed Iraqi forces out of Kuwait and continued to pursue them until the end of the game.

**2. Run #2: Heavy Scenario, Coalition Initiative**

This scenario was also developed devoid of Coalition intelligence, air defense, and air missions, again hampering Coalition forces. This scenario was designed to evaluate the Coalition response to a large Iraqi initiative *with* a large massing of Coalition forces on the Iraqi border.

Using the same starting scenario as shown in Figure 6 and described in the previous section, the simulation was re-scripted to include Allied command and control decisions which demonstrated seizure of the operational initiative. Despite the initial

posture of Iraqi forces, this scenario allows American forces to arrive in theater without interruption and fully deploy to defensive positions by the close of Day One. Additionally, a lack of Iraqi offensive activity allows for American air and ground attacks to initiate action against defending Iraqi forces. The American plan was to advance the 2/24th Mech to the same location in an attempt to build Allied combat power in that area.

The port at Dhahran was not damaged and therefore forces arriving through Dhahran were not delayed. The Iraqi 17th Armor Division was stopped by Coalition air attacks before it could engage Coalition forces in the west. By 1200 on Day Three, Coalition forces began their counterattack in the north and west. By late in the day, the Iraqi forces began to withdraw and Coalition forces pursued them with results similar to Run #1.

## F. LIGHT SCENARIO

In this scenario, the Iraqi forces have not entered Kuwait, but are only threatening to invade. Coalition forces were able to flow into Doha, Dhahran, and King Fahd International Airport (KFIA). At the beginning of the game, two Marine Expeditionary Units were poised near Doha, the 3rd Brigade of the 101st Airborne Division (3/101 ABD) was moving north toward Kuwait, and the 2/24th Mech was moving west towards KKMC. Initial force locations are shown in Figures 7 and 8.

### 1. Run #3: Light Scenario, Iraqi Initiative

Forces flowed into theater unhampered for the first 5 hours of the game until air strikes again damaged port operations. The results are similar to Run #1 in that arriving

forces were detained at the port while MHE was repaired. Iraq initiated an offensive 18 hours into the game, long before all Coalition forces had arrived in theater. The 3/101 ABD conducted a heliborne assault into northern Kuwait in an attempt to repulse the Iraqi offensive. Coalition forces already in position, coupled with arriving Coalition forces, were able to hold off the Iraqi attack. Iraqi forces began to withdraw between 24-30 hours into the game and were pursued by Coalition forces.

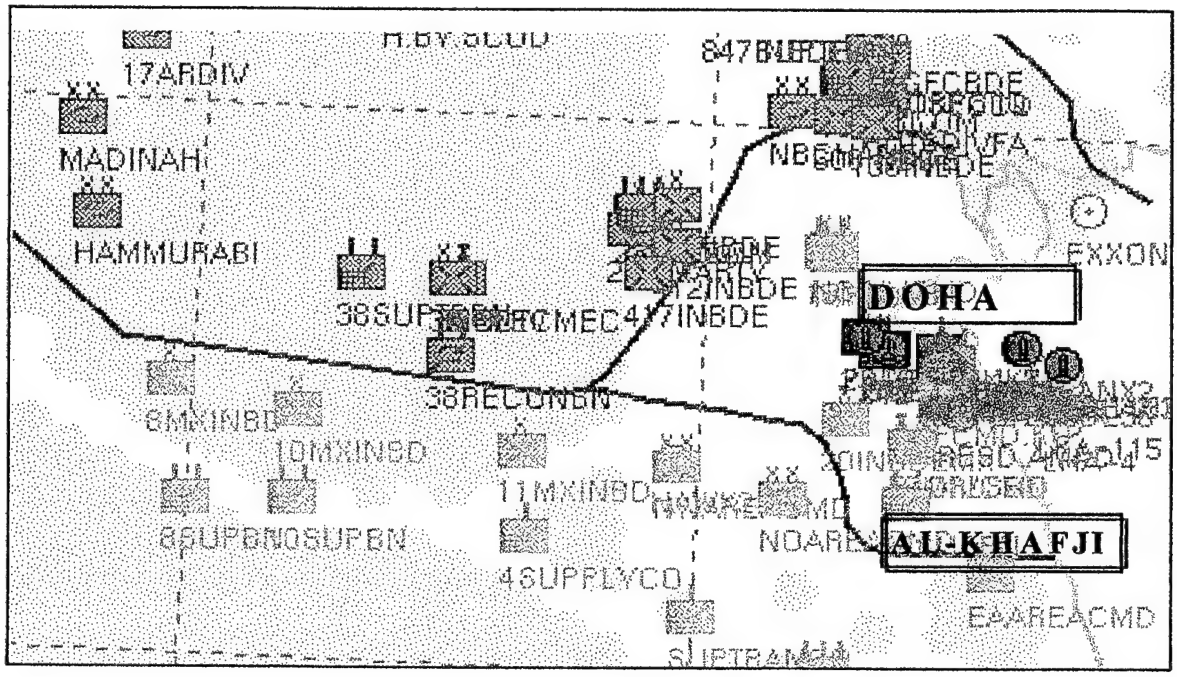



**Figure 7. Initial Force Locations near the Kuwaiti Border for Run #3 and Run #4.**

### 2. Run #4: Light Scenario, Coalition Initiative

This scenario is very similar to Run #3 with the major difference being that the port operations were not hampered and thus the majority of Coalition forces were able to flow into theater before the onset of hostilities. The heliborne assault was also not

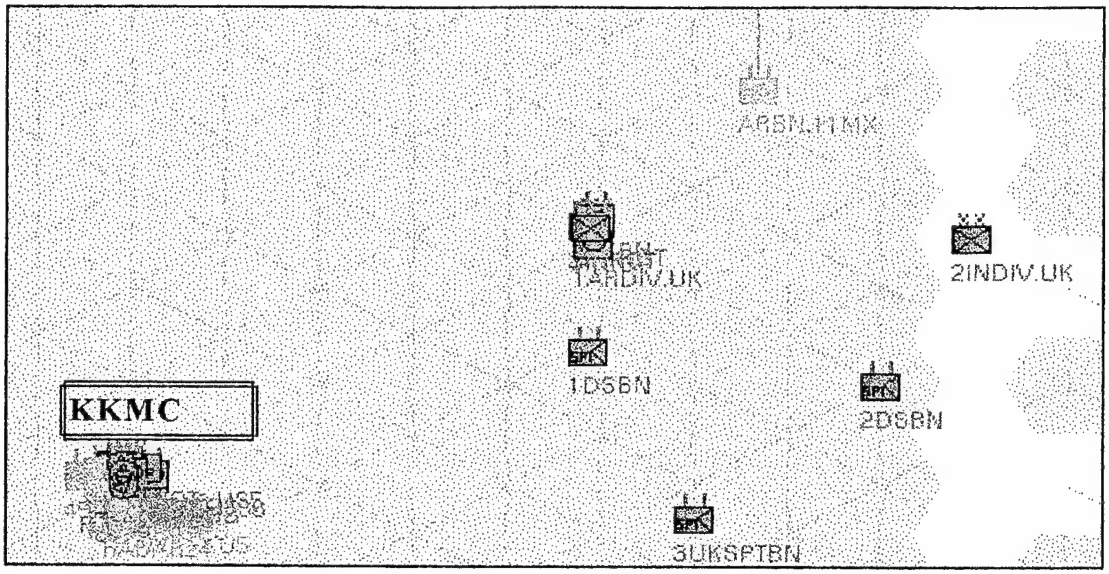



**Figure 8. Initial Force Locations near KKMC for Run #3 and Run #4.**

conducted, which allowed the Iraqi forces deeper penetration into Kuwait. Similar to Run #3, Iraqi forces were repulsed out of Kuwait and pursued into Iraq.

## G. NAVAL SCENARIO

In order to assure that certain critical event types occurred, several modifications were made to the scenario, as described in the remainder of this chapter. A carrier battle group, including a nuclear carrier (CVN), two Aegis cruisers (CGs) and other supporting elements, was steaming in the littoral waters in the vicinity of the Saudi-Kuwaiti border, as seen in Figure 9. The Iraqis were concentrating on the ground war effort raging on the Kuwaiti soil with the Gulf Cooperation Council and have devoted the full force of their air assets to achieving air superiority over Kuwait. Accordingly, the CVBG was on alert along a threat sector from 315T to 135T, which included the most likely avenues of attack from the Iranian air assets at the disposal of the current military leader. The CVBG surface

asset and CAP stationing was designed to optimize AAW capability along the expected threat sector. The surface assets were positioned so as to roughly split the sector of responsibility between the two Aegis cruisers and the supporting assets (Figure 9). Known air bases exist on the coast at Bushehr and inland at Shiraz – each with aircraft well within their combat radius and capable of inflicting serious damage on the battle group.

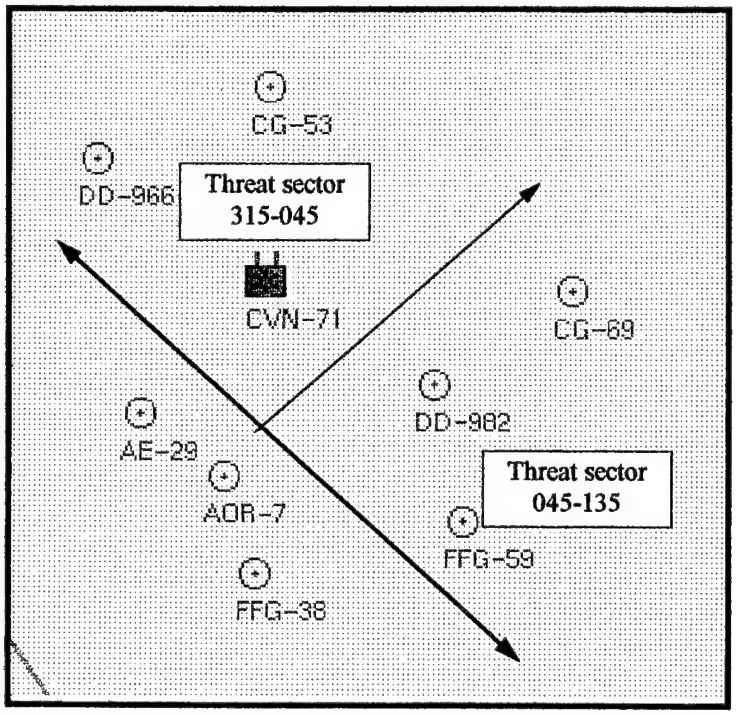



**Figure 9. CVBG Stationing Assignments in the Threat Sector**

Additionally, Figure 10 shows that missile sites existed on Kharg Island and that several Iranian naval vessels were deployed from Bushehr, armed with anti-ship cruise missiles, that were within weapons release range (WRR). The CVBG was in the Gulf to provide support, power projection and air cover for an impending amphibious landing and to assist in gaining and maintaining air superiority during the accompanying ground war

maneuvers. There were three combat air patrol (CAP) stations active and the carrier air wing was in "Alert Five" – aircraft on the deck of the carrier were prepared to launch within five minutes – for potential air activity from the enemy. At the commencement of the exercise, the Iranians were already declared "hostile" in a situation which allowed the engagement of all contacts not classified as "friendly."

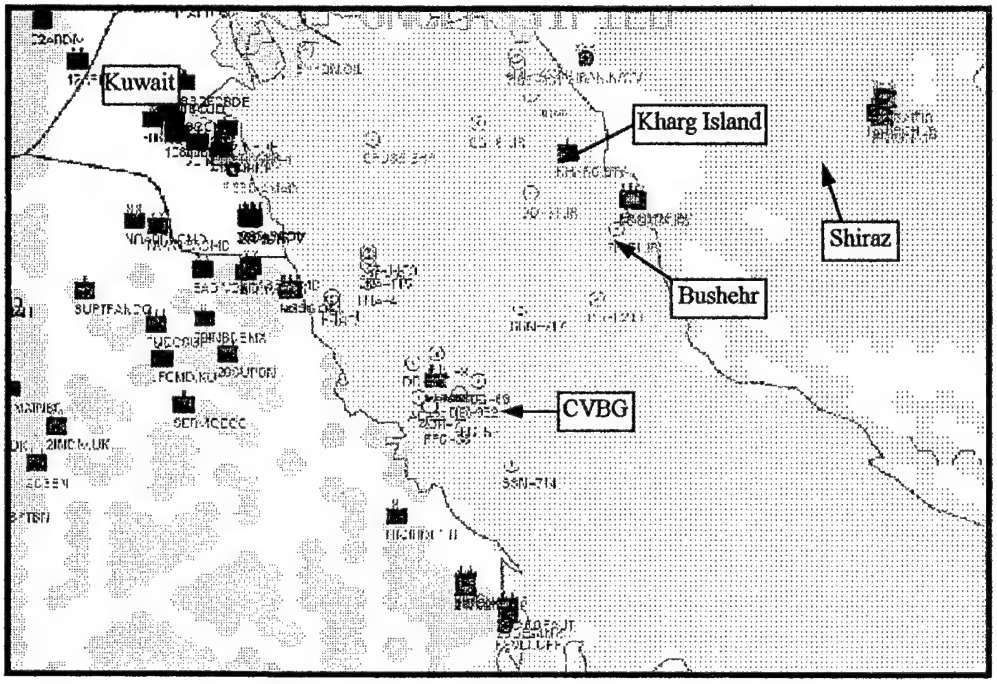



**Figure 10. Naval Scenario Force Locations**

## H. CRITICAL EVENT SELECTION

Critical Event One (selected from Run #1) involves the progress of the 2/24th Mech toward the objective area. After making steady movement toward KKMC during the first day, they were impeded by a successful Iraqi air strike at 0.625 days. Damage was simulated and the resulting time of repair induced further delays. The 2/24th Mech eventually reached KKMC and engaged the Madinah Division in battle, but the effects of

this delay were not clear. Madinah Division began to withdraw from contact at day 1.15 and endured a twelve hour conflict with the 2/24th Mech during their retreat. After this, Coalition forces lost contact with the Madinah, and the division was allowed to withdraw unimpeded. This chain of events is the basis for Critical Event One's causal audit trail analysis. This sequence yields an obvious question to ask: **Why was the Madinah Division allowed to withdraw unimpeded?**

Critical Event One (A) (also selected from Run #1) looks at a portion of the same aspect of the scenario, but from an Iraqi perspective. **How were Iraqi air forces able to locate and hit the 2/24th Mech with the previously mentioned air strike at 0.625 days?**

Critical Event Two (selected from Run #1) occurs in Dhahran, the embarkation point for all Coalition forces and logistics arriving in the theater. Coalition forces arrived into the theater unopposed until 1400 on Day One, when the port at Dhahran was hit with an Iraqi aerial attack. This caused units arriving through the port to be processed slower than usual for the next twelve hours because of the damage to the port's Material Handling Equipment (MHE). A queue built up as units waited at the port to be processed. As MHE was repaired, units waiting were processed according to their priority assigned in the TPFDD. This sequence of events raises the question: **Why was the Iraqi air strike against Dhahran successful?**

Critical Event Three (selected from Run #5) involves the Iranian forces' engagement of the CVBG and represents a modification of the current "real world" scenario. The strategy implemented by the Iranians against the U.S. Naval forces is

saturation of AAW capability through sheer numbers and the timely coordination of both air and cruise missile attacks by an enemy who represents neither a numerically nor technologically advanced force.

Early destruction of CVBG CAP aircraft and CVN, CG and DD engagement by ship and shore based cruise missiles resulted in loss of forward air defense capabilities, the loss of the carrier's ability to launch and recover aircraft and destruction of all escort units. **What factors enabled such horrific damage to be inflicted upon the U.S. Naval forces?**

Critical Event Three (A) (selected from Run #4) examines the naval scenario from an Iranian point of view. The Iranian forces engaged the CVBG with a devastating air and missile attack. The question arises: **How was the CVBG's position determined to enable the strike?**

# IV. CAUSAL AUDIT TRAIL ANALYSIS

## A. SUBJECTIVITY IN ANALYSIS

In theory, the causal audit trail process can trace the causal factors from any critical event down to the most minute detail of combat. In reality, the process' limiting factors are a lack of significant quantitative data and the inherent difficulty in representing subjective battlefield decisions quantitatively. The causal audit trail is best graphically presented as a version of a "decision tree." This tree attempts to delineate all the possible causal factors for a critical event, enabling the analyst to follow the path that leads to the most likely cause, based on quantitative data. The branches of the tree may end when the data required to determine the cause of a course of action is not available, or when the analyst is faced with finding the cause of a commander's *subjective* decision.

The concept of being faced with a "subjective dead end" while performing wargaming analysis is further documented by Coleman Research Corporation's (CRC) efforts to quantitatively evaluate the *entire* UJTL [Ref. 15]. As seen in Tables 2 and 3, CRC concluded that of the 5199 UJTL tasks and their subordinate elements, 4571 were capable of being objectively quantified.

| UJTL | Strategic National | Strategic Theater | Operational | TOTAL |
|---|---|---|---|---|
| Tasks | 7 | 8 | 6 | 21 |
| Subtasks | 35 | 31 | 31 | 97 |
| Supporting Tasks | 136 | 121 | 136 | 394 |
| Measures | 1526 | 1865 | 1808 | 5199 |

**Table 2. UJTL Breakdown .**

| Objective | 4571 |
|---|---|
| Subjective | 255 |
| Uncertain/Either | 373 |

**Table 3. Breakdown of objective and subjective tasks.**

The remaining subjective or uncertain tasks leave several aspects of combat unmeasurable. When faced with judgments about these aspects of combat while doing a causal audit trail analysis, one alternative is to end that portion of the causal audit trail "tree" at the given subjective point.

Another alternative at this point of the audit trail analysis is to examine more closely the concept of subjectivity. Currently, the only capabilities analysts have in developing the causal audit trail are quantitative items such as exact time, place and strength of a unit where the critical event occurred. If all logically required assets are present and functioning at the time of the critical event, then it might be said that the event occurred due to the stochastic nature of the model. This is the realism imparted by stochastic models. For example, a Patriot missile battery may be on station, but Scuds may still penetrate its defenses. Any enemy threat that is adequately defended against still has a positive probability of defeating planned defenses.

The situation gets more difficult to evaluate when pieces seem to be missing from the puzzle. If, for instance, a major supply depot is destroyed by *undetected* enemy air and it is subsequently discovered, via the audit trail, that the depot was virtually unprotected, the CINC will want to know *why*. The quantitative nature of an audit trail provides analysts no ability to answer the question of *why* various events took place, only that they did. In the context of the supply depot example, the analyst can discover that

there was an air defense unit located nearby, but not near enough to, the supply depot. The question of *why* the unit wasn't close enough to be effective still remains. Answering the question of *why* during post-CAX analysis requires that the audit trail somehow be expanded to fill in the information gap concerning the subtle reasons why various allocations of scarce resources were made.

One possible method of filling in this information gap is through the consideration of human factors in decision making. To review, one of the purposes of a CAX is to train decision makers by giving them a forum in which to make decisions in as near a real environment as can be produced. The very making of those decisions is the focus of the subjective end of a causal audit trail. The subjectivity of an audit trail can be evaluated only once methods are devised to gather, as unobtrusively as possible, data on *why* decision makers choose one option over another.

Every decision maker has a thought process that is exercised before making a final decision. In the context of the location of an air defenses base, the officer in charge of locating the Patriot battery had dozens of factors influencing his final decision. Which factors played the most important roles in his decision? Was he concerned with the battery's tactical location? Did he feel that terrain characteristics of the location were a factor? Did he misinterpret his commander's orders? Did he not get enough sleep the night before he relocated the missile battery, causing him to position it incorrectly? The last question may seem irrelevant, but it demonstrates that almost *anything* could have been the deciding factor in this decision maker's choice.

The focus of this issue is the capturing of information that addresses these factors. This can be **attempted** through several means. One option is to closely observe wargame participants and their environments in order to better judge the players' states of mind and how these surroundings affect thought processes. Another option is to survey participants after the wargame in order to better assess the condition under which key player interaction decisions were made. An example of a possible survey question follows:

> The commander's intent I was given is clear and allows me to make this decision with a high degree of confidence:
>
> (A) Strongly Agree
> (B) Agree
> (C) Neither Agree nor Disagree
> (D) Disagree
> (E) Strongly Disagree

The survey concept could be expanded to allow for input of prose if the respondent desired. This would allow for explanation of potential problem areas. This process could assist in finding the root causes of many critical events by analyzing critical decisions made prior to the events. Often participants know when a scenario is not producing favorable results, and many would value a chance to explain or justify their actions and decisions. This approach can also have its drawbacks. Players asked to recall the events of the game after the fact tend to exhibit a "selective" memory, heavily influenced by the outcome of the scenario. In short, people tend to remember what they want to remember.

In the case of the Patriot battery, the officer in charge might have liked an opportunity to say that he was "over tasked," could not adequate defend two supply depots, and decided to locate closer to one than the other. Finding this explanation linked

to his last movement order would provide post-CAX analysts an ability to report *why* the one supply depot was left undefended.

## B. INFLUENCE OF TRAINING OBJECTIVES ON ANALYSIS

The shape and breadth of a causal audit trail are greatly influenced by the training objectives of a wargame. For example, a CINC desiring to measure a staff's performance of OP 6.1.4 (Counter Enemy Air Attack in Theater of Operations/ JOA) would orchestrate a scenario rich in AAW units, AAW engagements, etc. The CINC would ensure that the scenario contains a dynamic AAW element in the foreground and more scripted representations of other areas of combat in the background. By scripting certain combat interactions, the AAW aspects of the scenario may cause the causal audit trail to become somewhat one dimensional.

The nature of a wargame scenario's script is influenced by more than just CINC guidance. Scenario development is a continual process. The flexibility of large scale exercises facilitates impromptu changes to ensure that the accomplishment of training objectives is realized. If the decisions made by wargaming personnel are not resulting in training objectives being met, wargame developers may change the scenario during the exercise by altering force strengths, force deployments, etc. Thus, causal audit trail analysis may become disjoint over the entire exercise if scenario changes are made after exercise start.

## C. EVENT ONE: THE MADINAH WITHDRAWAL

In Brown's [Ref. 5] efforts to measure successful operational maneuver, he states that "some method of quantifying the first order effects of operational art must be determined." He continues to say that this representation must include more than simply using the speed of any given combat system, or aggregation of systems. Instead, it must be relational, taking into account the operational maneuver of both friendly and enemy forces, as well as the descriptive characteristics of the units over time.

The need for a relational descriptive parameter led to Brown's development of a measure of performance that is called the Fractional Closure Rate, or FCR:

$$FCR_{f,e}(t) = \frac{DISTANCE_{f,e}(t-\Delta t) - DISTANCE_{f,e}(t)}{MAX\left[DISTANCE_{f,e}(t-\Delta t), DISTANCE_{f,e}(t)\right]}, \forall f, e, t$$

where f= a specified friendly maneuver element or target
e= a specified enemy maneuver element or target
t= time of capture of the data

The numerator of the FCR is a representation of the closure distance between two forces in some time interval, $\Delta t$, or more simply the approach velocity of two forces. Dividing by the maximum of the current distance between forces creates a measure which has the flexibility of demonstrating negative change in relation to the closure. Withdrawing at a certain distance has a negative FCR of the same magnitude as an advance at the same distance.

Brown further explains that "the Fractional Closure Rate is developed only as a measure of performance to be incorporated into a measure of effectiveness for maneuver. It does have some stand-alone use as a measure of effectiveness of the ability of a force to

maintain a high operational tempo. This translates into a quantitative measure of initiative and agility, using depth of attack as the data element." [Ref. 5]

Brown's first application of the utility of the FCR to wargaming is an analysis of Critical Event One, the Madinah withdrawal. The progress of 2/24th Mech's movement westward toward KKMC is exhibited in Figure 11, with curve behavior pointing to causal events which impede or facilitate that progress. The trend line, shown in black, uses every three data points to calculate a moving average, which is a characteristic representation of the overall trends in initiative and momentum.

A slow, but successful movement toward the objective area is demonstrated by the gradual rise in FCR from first movement until the delay caused by the Iraqi air strike at time 0.625. Damage is simulated and the resulting time of repair induces further delays. This, in turn, produces a drop in momentum until the completion of the first day. Additionally, the initiation of the ground offensive by the Madinah Division creates movement away from the 2/24th Mech's static location, further decreasing the closure. As the damage is repaired, the closure ratio begins to increase rapidly for approximately 0.25 days, or six hours. During this time the 2/24th Mech is able to close on KKMC and the Madinah Division, and join the battle. The more pronounced spatial acceleration, or slope of the FCR, is the result of the relational movement of the two forces moving toward the same location at this point in the battle. Madinah's movement was necessary to initiate ground combat with forces already at KKMC, thereby maintaining the operational initiative.

As Madinah begins to withdraw from contact at time 1.15, the FCR initially drops off before stabilizing back to the gradual rise exhibited in the first few hours of the scenario. At this point in the battle Madinah begins to lose its momentum, and the unimpeded 2/24th Mech closes and joins battle at approximately time 1.5. For the next twelve hours, the Coalition force is able to create a favorable tempo, but has arrived well after the Iraqi force was able to withdraw. Though creating a favorable FCR from time 1.5 to 2.0, it is occurring at the expense of pursuing an enemy with whom they still have not gained contact. Finally, at the beginning of the second day, Madinah continues its withdrawal uninhibited by Coalition efforts. The curve characteristics at this point are useful to a CINC in evaluating the exercise. The defeated Iraqi force is able to reduce the FCR. This translates to an inability to prevent a force from escaping the battle area. If this were intentional, then the curve is simply an affirmation that the plan was properly conducted. If not, this analysis portrays the inability of the 24$^{th}$ Mech to maintain the tempo and create a favorable FCR with respect to the Iraqi forces.

The Madinah Division executes the withdrawal along with the Hammurabi Division. The movement is from the KKMC area of operations to support forces along the coast. Given the lateral movement of the Iraqi forces, a successful counterattack plan would have slowed the withdrawal.

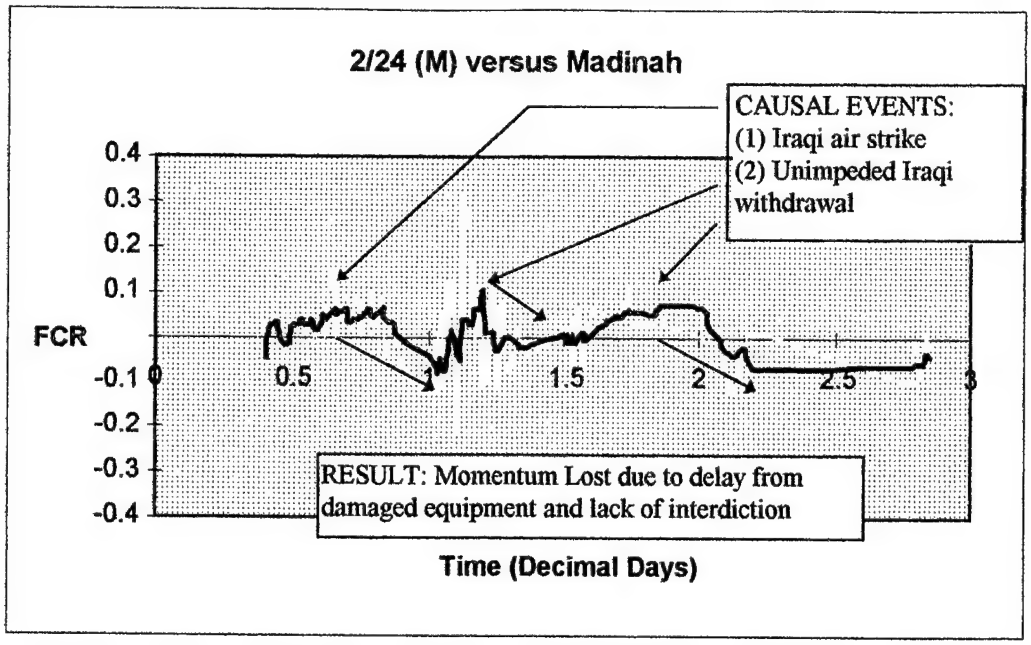



**Figure 11. Effects of Interdiction on Closure.**

The "decision tree" for Event One, the Madinah withdrawal, is shown in Figure 12. To answer the previously mentioned question of why the Madinah Division was allowed to withdraw unimpeded, the possible broad categories of causes must be delineated. Was it due to poor intelligence, 2/24th Mech's lack of mobility, a supply shortfall, low force strength, prior tasking of 2/24th Mech, or was this sequence of events a result of Coalition operational tactics?

**Did this critical event occur because of an operational tactical decision?** This is the first of Critical Event One's branches, and it quickly ends. If not following Madinah was a tactic that was decided upon by the Coalition chain of command, subjective audit trail techniques described in Section A of this chapter would be used.

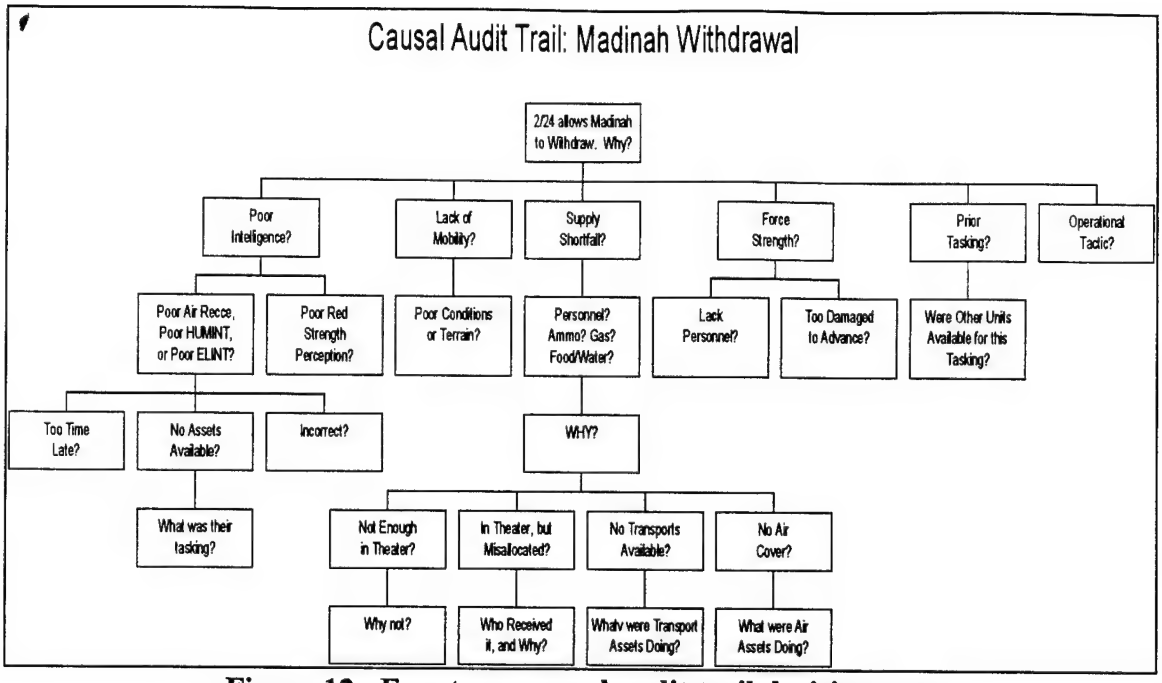



**Figure 12. Event one causal audit trail decision tree.**

**Did 2/24th Mech have any prior tasking that would somehow impede their pursuit of Madinah?** In order to investigate this question, the 2/24th Mech's mission and posture data during the period leading up to Madinah's withdrawal must be analyzed. Every unit in JTLS has both a mission and a posture. "The mission is generally the last thing the unit was ordered to do. The posture describes what the unit is actually doing [Ref. 12]." This information is available in chronological order in 2/24th Mech's Unit Change List (Table 4), which shows that 2/24th Mech is in a MOVING posture from day 0.5526 to 0.6648, when it shifts to a DEFEND posture, then back to MOVING at 1.0013. It then briefly shifts back to DEFEND at day 1.1169 until 1.5007. A unit's posture changes from MOVING to DEFEND when the unit's movement is complete or the unit comes under fire [Ref. 12]. Since 2/24th Mech is not in combat at any time, this change in posture at 1.1169 is due to its arriving at its objective at KKMC. A unit will assume an

ATTACK posture only in response to a player order [Ref. 12]. This is the case with 2/24th Mech at time 1.5007. 2/24th Mech's posture shifts to ATTACK because of a

| Scenario Time of Posture Status Change | 2/24's Posture | In Combat? | Madinah's Posture | In Combat ? |
|---|---|---|---|---|
| .5526 | MOVING | NO | ATTACK | NO |
| .6648 | DEFEND | | ATTACK | NO |
| .9167 | DEFEND | | DEFEND | YES |
| 1.0013 | MOVING | | ATTACK | YES |
| 1.0016 | MOVING | | WITHDRAW | YES |
| 1.1169 | **DEFEND** | | WITHDRAW | YES |
| 1.5007 | ATTACK | | WITHDRAW | NO |
| | | | | |
| | | | | |
| | | | | |

Start of Madinah's Withdrawal.

**Table 4. Summary of Postures for 2/24th Mech and Madinah.**

player issued order to attack the withdrawing Madinah division. These observations tell the analyst that 2/24th Mech had the correct mission and posture to follow Madinah, eliminating this as a possible cause for the critical event.

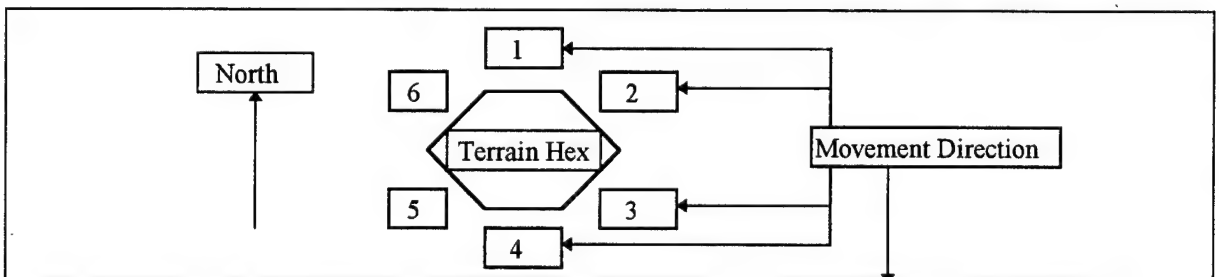
Continuing the investigation of "prior tasking," the next logical issue is to determine whether any other Coalition ground units in the area could have performed the mission of following Madinah. To do this, the postprocessor must report which other Coalition units with similar functions were within a 100x100 mile square of Madinah when it began to withdraw at day 1.0016. These results are seen in Table 5. Of the six

| Unit Name | Unit Type | Latitude | Longitude. |
|---|---|---|---|
| 10MXINBD | GROUND | 27.6593833 | 45.6553501 |
| 10SUPBN | DEPOT | 27.6666667 | 45.6666667 |
| 1ARDIV.UK | GROUND | 27.15 | 45.65 |
| 1DSBN | DEPOT | 27.0666667 | 45.6333333 |
| 2DSBN | DEPOT | 27.3 | 45.6333333 |
| 2INDIV.UK | GROUND | 27.3833333 | 45.65 |

**Table 5. Coalition units < 100 miles of Madinah at the time of their withdrawal.**

Coalition units in the vicinity , only three are the proper type of ground unit that could have performed this mission. Continuing the audit trail, the next step is to report what 10MXINBD, 1ARDIV.UK, and 2INDIV.UK were doing at the time of the MADINAH withdrawal. These results are given in Table 6.

Clearly, 1ARDIV.UK and 2INDIV.UK are engaged in combat, making them incapable of pursuing Madinah. This leaves 10MXINBD, a mixed infantry brigade, as the only other possible candidate to pursue Madinah. From this point, the audit trail would then follow the subjective path of why 10MXINBD was not assigned the mission of helping 2/24th Mech to track down Madinah. Perhaps the Coalition chain of command




| Unit | % Strength | Posture | Mission | Direction | In Combat? |
|---|---|---|---|---|---|
| 10MXINBD | 98.21 | DEFEND | DEFEND | 1 | NO |
| 1ARDIV.UK | 95.6 | DEFEND | DEFEND | 1 | YES |
| 2INDIV.UK | 90.31 | DEFEND | DEFEND | 1 | YES |

**Table 6. Status of Coalition ground units in vicinity of Madinah withdrawal.**

assumed that 2/24th Mech, being the closest unit to Madinah, would be able to trail them without assistance or that 10MXINBD was more valuable to the Coalition cause in some other capacity.

**Was 2/24th Mech's force strength a factor in allowing Madinah to withdraw?**

This question can be answered by analyzing the trends in 2/24th Mech's percent strength

throughout the scenario. The 2/24th Mech's percent strength never falls below 99.45% during the entire scenario, so it can be reasonably assumed that this factor played no role in the scenario's outcome.

Continuing the analysis of 2/24th Mech's possible weaknesses, one can query the status of 2/24th Mech's combat systems data. As seen in Table 7, the JTLS post-processor can output when each unit's level of a particular combat system changed, the reason for the change, and the new "level" of that combat system. After review of all of the 2/24th Mech's combat systems, none are depleted; thus ending this branch of the causal audit trail tree. If this analysis had revealed deficiencies in one or more combat systems areas, the following would also need to be queried:

| TIME OF CHANGE | COMBAT SYSTEM CATEGORY | NEW CS LEVEL |
|---|---|---|
| 0.001 | AFV | 6 |
| 0.041667 | AFV | 90 |
| 0.6448222 | AFV | 90 |
| 0.001 | APC | 25 |
| 0.6448222 | APC | 95 |
| 0.6448222 | APC | 95 |
| 0.6448222 | APC | 95 |
| 0 | C3I | 4 |
| 0.001 | C3I | 4 |
| 0.6448222 | C3I | 4 |
| 0.001 | HAW-ATGM | 12 |
| 0.001 | HAW-ATGM | 36 |
| 0.6448222 | HAW-ATGM | 36 |

**Table 7. Sample of Combat System Change JTLS Postprocessor Table.**

- The time of the damage.
- The unit change data associated with that particular time.
- The supporting force in the area.
- The quality of the unit's intelligence.

- The unit's detailed supply status.

**Was the 2/24th Mech's supply status a factor in allowing Madinah to withdraw?** The type of analysis that was performed on the 2/24th Mech's combat system data can be repeated for supply data to determine if a unit had deficiencies in any of its Supply Categories (SC). As seen in the Supply Category Change (SCC) file (Table 8), the JTLS postprocessor can report the type of supply, the time its level changed, its new value, and the reason it changed. As was evident with 2/24th Mech's combat system changes, none of their supply categories were reasonably depleted at the time of Madinah's initial withdrawal. Had there been more variability in the levels of supplies, the analysis would then have to be taken to the level of establishing critical levels of each

| SCC SC Name | SCC Time | SCC Attribute | SCC New Value | SCC Reason |
|---|---|---|---|---|
| CL.I (SUBSISTENCE ITEMS) | 0 | DUE IN | 0 | INITIAL DATA |
| CL.I | 0.001 | REORDER | 15.249 | UNIT ATTACHED |
| CL.I | 0.25 | ON HAND | 28.3953 | CONSUMED |
| CL.I | 0.5 | ON HAND | 26.9006 | CONSUMED |
| CL.I | 0.75 | ON HAND | 33.71914636 | CONSUMED |
| CL.I | 1 | ON HAND | 31.77689636 | CONSUMED |
| CL.I.W (WATER) | 0 | DUE IN | 0 | INITIAL DATA |
| CL.I.W | 0 | BASIC LOAD | 4581 | INITIAL DATA |
| CL.I.W | 0.001 | DUE IN | 0 | UNIT ATTACHED |
| CL.I.W | 0.001 | BASIC LOAD | 47947.8 | UNIT ATTACHED |
| CL.I.W | 0.001 | ON HAND | 151593 | UNIT ATTACHED |
| CL.I.W | 0.25 | ON HAND | 248542.2835 | CONSUMED |
| CL.I.W | 0.375 | ON HAND | 248480.104 | COMBAT USAGE |
| CL.I.W | 0.416 | ON HAND | 248417.9245 | COMBAT USAGE |

**Table 8. Sample of Supply Category Change JTLS Post-processor Table.**

supply type. For each apparent supply shortfall using these criteria, the following information would be considered in the analysis:

- The status of available supply transportation.
- The availability of air cover for the associated transports.

- The amount of the particular deficient supply category that is available in theater.
- The names and locations of other units or sites with this resource available.

**Was 2/24th Mech hampered by lack of mobility, somehow not allowing them to follow Madinah?** The first bit of information needed for this portion of the analysis is the terrain type in the vicinity of both units. Throughout the entire scenario, Madinah and 2/24th Mech travel through hexes that belong to one of the three following categories: open terrain, rubbled cities, or forests with good roads. All of these are considered to be "minimally limiting terrain" by JTLS movement algorithms, so the factor of terrain type can be eliminated as an important factor in the scenario's outcome.

**Was allowing Madinah to withdraw a result of poor Coalition intelligence?** This branch of the decision tree would be essential in most scenarios, but due to the composition of Coalition and opposing forces in this wargame, intelligence played an almost nonexistent role in the Coalitions forces' detecting of Iraqi forces. The HUMINT and ELINT assets available to the Coalition forces were not used, which was a conscious decision on the part of the designers of the experiment. This artificiality was imposed for the purpose of enhancing the quantity of ground combat available for analysis. Had Coalition air forces been used, the possibility of opposing ground forces being quickly eliminated seemed very likely.

The 2/24th Mech receives accurate updates of Madinah's location whenever Madinah's location changes and 2/24th Mech is within the range of its given sensors. These sensors may be radars, intelligence sources, or in this case, visual. When not within

sensor range of Madinah, 2/24th Mech perceives them to be at their last known location (Figure 13). This figure shows the distance, in nautical miles, between Madinah's actual location and where 2/24th Mech *perceives* Madinah to be. As could be expected, the graph follows the timeline of the scenario: after making steady movement toward KKMC and staying close to Madinah early on the first day, 2/24th Mech was impeded by a successful Iraqi air strike at 0.625 days. Damage was simulated and the resulting time of repair induced further delays. The 2/24th Mech eventually reached KKMC and engaged the Madinah Division in battle. Madinah then began to withdraw from contact at day 1.0016 and endured a twelve hour conflict with the 2/24th Mech during their retreat. After this, Coalition forces lost contact with the Madinah, and the division was allowed to withdraw unimpeded.

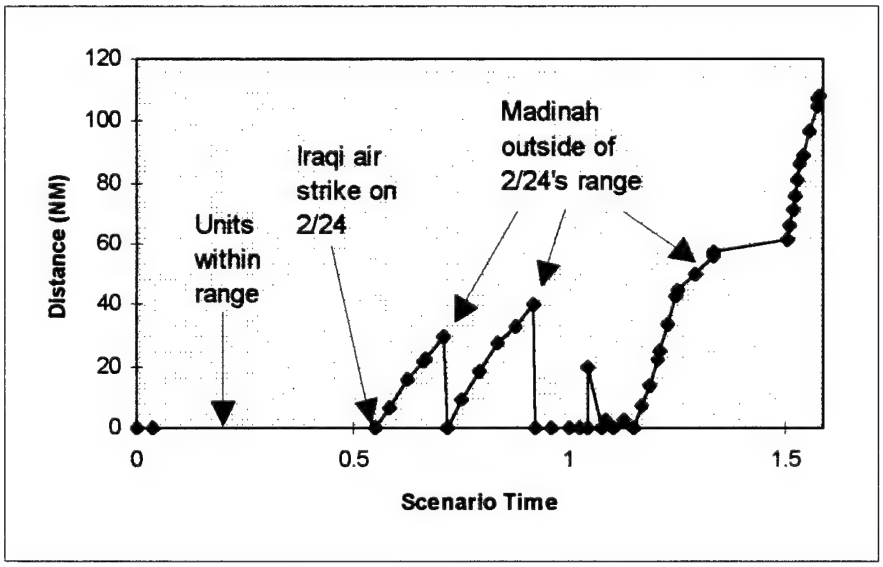



**Figure 13. Difference between Madinah's perceived and actual locations.**

Of all possible branches of the causal audit trail tree, this is the most plausible. The reason 2/24th Mech did not follow Madinah in its withdrawal was almost certainly the fact

that they did not know where Madinah was. Once Madinah exceeded the range of 2/24th Mech's sensors, there were no other Coalition forces close enough to find this elusive Iraqi unit.

Similar analysis of the perception of force strength is shown in Figures 14 and 15. The 2/24th Mech maintains an accurate picture of Madinah's force strength until they begin their withdrawal at Day 1.0016 where, due to the increased range, 2/24th Mech slightly underestimates Madinah's force strength. This can also be attributed to the lack of Coalition intelligence assets. The only Coalition asset available to assess the strength of Madinah is 2/24th Mech, since it is the only unit within range to perform this task.

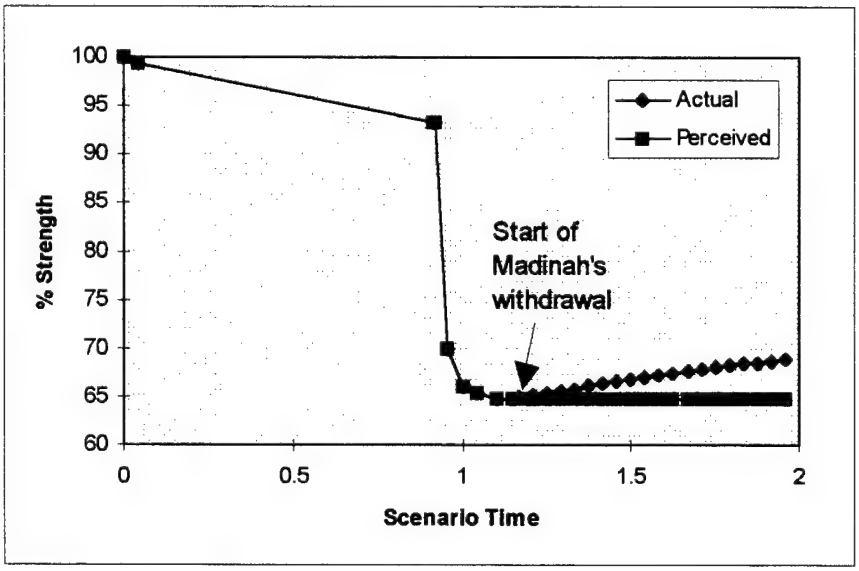



**Figure 14. Madinah's perceived and actual strength vs. time.**

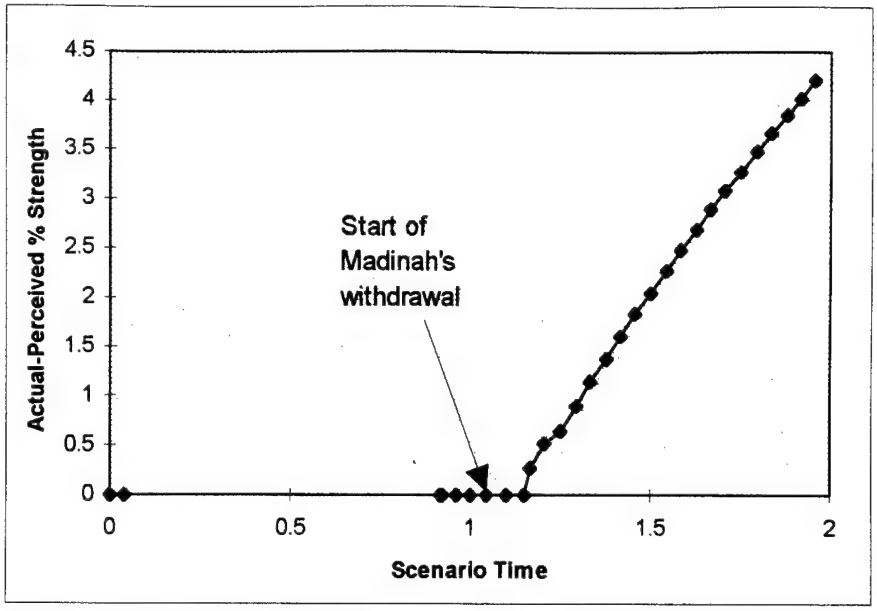



**Figure 15. Difference between perceived and actual strength vs. time.**

Had the scenario included other intelligence related data, the following elements would be essential for analysis of the critical event:

- Reports of all the organic intelligence data regarding Madinah forwarded during the entire scenario and comparisons with the actual times of events to determine the age of the information.
- Reports of which Coalition air recce assets were available and their tasking during the period leading up to Madinah's withdrawal.
- Reports of all air recce intelligence data forwarded during the given period of inquiry and comparisons with the actual times of events to determine the age of the information.

- Reports of all Coalition ELINT and HUMINT assets available during the given period of inquiry and their tasking during the same period.
- Reports of all ELINT and HUMINT data forwarded during the given period of inquiry and comparisons with the actual times of events to determine its relevance.

Searching for the most likely cause of this critical event reveals that the "poor intelligence" branch of the causal audit trail tree is the likely cause. Ignoring any potential subjective decisions that may have affected this scenario, the Coalition forces' most glaring Achilles' heel was their inability to track the enemy. This can be attributed almost entirely to their complete lack of deployed intelligence assets.

## D. EVENT ONE (A): 2/24TH MECH AIR STRIKE, THE IRAQI PERSPECTIVE

An interesting parallel to the audit trail of Event One is a similar analysis from an Iraqi perspective. While trying to answer the question of how Iraqi forces are able to locate and hit the 2/24th Mech with an air strike, some additional facts about the scenario are revealed.

Due to information already known about this scenario from the analysis of Event One, the causal audit trail decision tree of Event One (A) (Figure 16) is relatively small. The two primary questions to be answered to audit this event are discussed below.

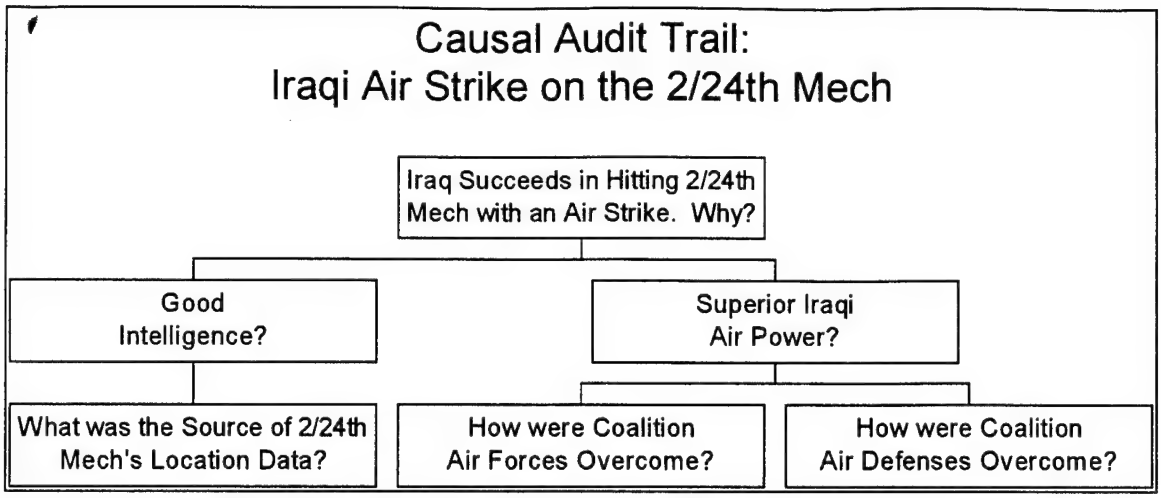



**Figure 16. Event 1 (A) causal audit trail decision tree.**

**Was the strike successful due to superior Iraqi air forces?** In trying to ensure a successful Iraqi air strike, no Coalition air missions were flown in this variation of the scenario. For the same reason, the ROE for all Coalition air defense units were configured to allow no Coalition surface-to-air engagements with attacking Iraqi air forces. The combination of these factor made the 2/24th Mech, once found, an easy target.

**How were the Iraqi forces able to locate the 2/24th Mech?** Contrary to the lack of Coalition intelligence employed in this scenario, there *was* a limited amount Iraqi intelligence that enabled their forces to locate Coalition units. The intelligence came in the form of three Iraqi armed reconnaissance air missions flown during the scenario (Table 9). These missions were put into the scenario to patrol the air space near the Coalition forces

| Mission Number | Launch Time | Initial Search Point | Units / Targets Engaged |
|---|---|---|---|
| 2BDE24_281300 | 0.5321 | 26.45 / 48.62 | NONE FOUND |
| 2BDE24_281345 | 0.5630 | 26.45 / 48.62 | NONE FOUND |
| 2BDE24_ASAP | 0.6050 | 26.83 / 46.82 | 2BDE24MX |

**Table 9. Summary of Iraqi Armed Reconnaissance Air Missions**

and engage any Coalition units they could find. Their area of patrol was explicitly input by game developers to cover the 2/24th Mech's route to KKMC, hoping that at least one of these missions would detect the 2/24th Mech, engage it, and delay their progress to their objective. The third of the three missions did just that; launching at time 0.6060 then detecting and hitting the 2/24th Mech with an air strike at time 0.6250. The desired objective of the game controllers was to hit the 2/24th Mech with an air strike to evaluate its effect on their pursuit of Madinah, and they made this happen by leaving the 2/24th Mech essentially defenseless against air attack.

## E. EVENT TWO: THE DAHRAHN AIR STRIKE

Figure 17 shows the causal audit trail decision tree for Critical Event Two, the Dahrahn air strike.

**Did poor intelligence contribute to the success of Iraq's air strike on Dahrahn?** As discussed in the previous analysis of the Madinah withdrawal, very limited intelligence assets were played in this scenario. The following data elements would need to be queried if the given scenario produced significant intelligence data:

- Reports all organic intelligence data regarding the opposing strike force forwarded during the period leading up to the air strike and comparisons with the actual times of events to determine the age of the information.
- Reports of all tasking of Coalition air recce, ELINT, and HUMINT assets at the time of the attack.

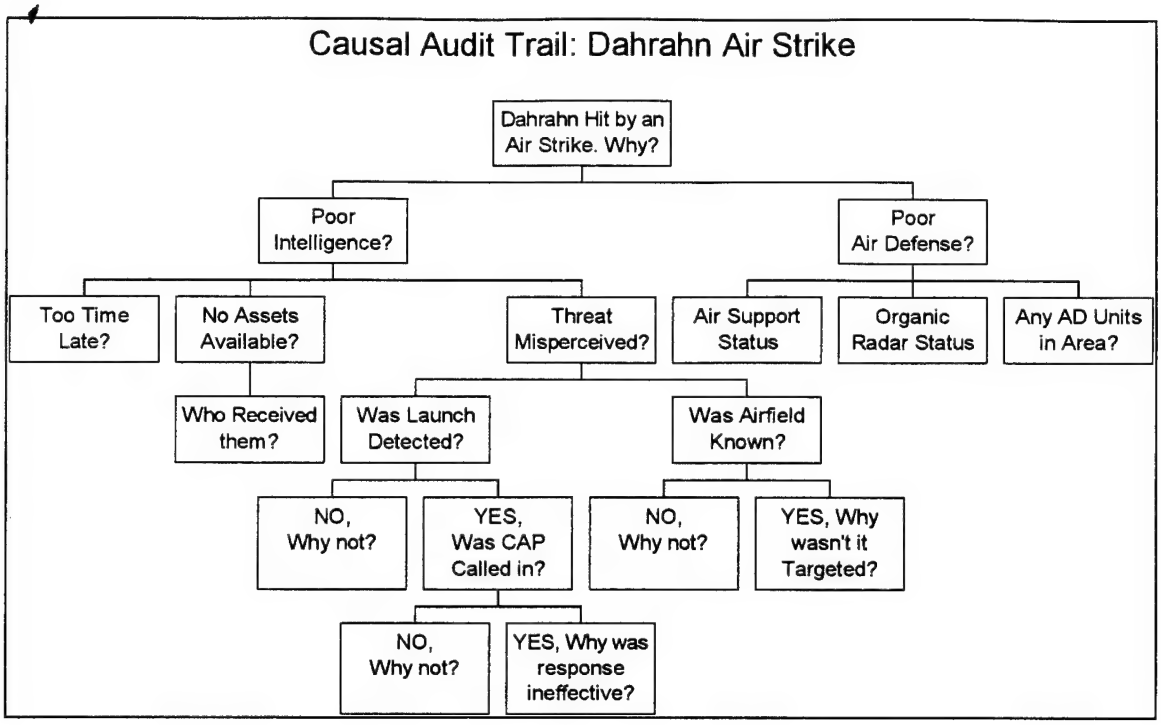



**Figure 17. Event 2 causal audit trail decision tree.**

- Reports of all air recce intelligence, ELINT, and HUMINT data forwarded during the given period of inquiry, with comparisons to the actual times of events to determine the lateness of the data.
- Reports indicating if intelligence regarding the launch of the opposing strike aircraft was forwarded.
- Reports of the results of CAP missions, if they were called in.
- Reports indicating if any intelligence regarding the location of the opposing strike force home airfield was *ever* forwarded.
- Reports indicating if the given airfield was *ever* targeted by Coalition strike missions.

**Did poor air defense or a lack of air defense contribute to Iraq's success in carrying out the air strike on the port of Dahrahn?** This question is answered by analyzing the composition of the Coalition units in the vicinity of Dahrahn during the air strike. To do this, the postprocessor must report all Coalition units with air defense capabilities within 50 miles during the air attack. Table 10 lists all of the Coalition units within a 100x100 mile box surrounding Dahrahn. Once this information is known, the analyst must then determine the composition of each unit to determine whether it has air defense capabilities. To do this, one must query the database available in the JTLS On-line Player's Manual (OPM). Among other things, the OPM lists each unit's SAM/AAA

| UNIT | TYPE | UNIT | TYPE | UNIT | TYPE |
|---|---|---|---|---|---|
| 1-11FABN | GROUND | 2-9FABN | GROUND | D-3-41FAB | GROUND |
| **1-2ADBN** | **GROUND** | 24DIVARTY | GROUND | **HQ2BDE101** | **GROUND** |
| 1-5INBN | GROUND | **2ARBDE1AR** | **GROUND** | XVIIIFA | GROUND |
| 1-8ARBN | GROUND | 3-2ADABN | GROUND | 18COSCOMR | DEPOT |
| 1-9FABN | GROUND | 3-41FABN | GROUND | 1DISCOMR | DEPOT |
| 11FABDE18 | GROUND | 3-9FABN | GROUND | 1-229ATKH | SQDRON |
| **1ARBDE1AR** | **GROUND** | **3ARBDE1AR** | **GROUND** | 2-159ATKH | SQDRON |
| 1BDE24MX | GROUND | 3ARCAVRGT | GROUND | 229ATKGP | SQDRON |
| 2-11FABN | GROUND | D-1-2ADBN | GROUND | | |
| 2-12ARRGT | GROUND | D-24DIVAR | GROUND | | |

**Table 10. Coalition Units within 100 x 100 box of the Port of Dahrahn.**

targets, such as Stinger batteries, Patriot batteries, etc. Table 11 lists those units with air defense capabilities and shows that these four units had the weapons necessary for an

| Unit Name | Air Defense Assets |
|---|---|
| 1-2ADABN | 2 Stingers with 11 Firing elements each |
| 1ARBDE1AR | 1 Patriot battery with 6 Firing elements |
| 2ARBDE1AR | 1 Patriot battery with 6 Firing elements |
| 3ARBDE1AR | 1 Patriot battery with 6 Firing elements |
| HQ2BDE101 | 2 Stingers with 11 Firing elements each |

**Table 11. Air Defense Units near Dahrahn.**

attempted defense of the port of Dahrahn from the opposing strike force.

- **What were these units doing during the period leading up to the air strike?**

The answers to this question can be seen by reviewing the unit change list for each unit, as shown in Table 12. This table indicates that none of the air defense units in the vicinity of the port of Dahrahn were in combat during the entire scenario. A scan of the postprocessor's air engagement file reveals that *there were* ***no*** *Coalition SAM engagements during the entire scenario.* The reason for these unusual circumstances is

| Unit Name | Time | Posture | Mission | Strength | In Combat? | Orientation |
|---|---|---|---|---|---|---|
| 1-2ADBN | 1.90665 | DEFEND | DEFEND | 99.51 | NO | 1 |
| | ↓ | " | " | ↓ | " | " |
| | ↓ | " | " | ↓ | " | " |
| 1ARBDE1AR | 1.5001 | DEFEND | DEFEND | 99.63 | NO | 1 |
| | 2 | DEFEND | DEFEND | 99.56 | NO | 1 |
| | 2 | DEFEND | DEFEND | 99.52 | NO | 1 |
| | 2 | DEFEND | DEFEND | 99.51 | NO | 1 |
| | ↓ | " | " | ↓ | " | " |
| | ↓ | " | " | ↓ | " | " |
| 2ARBDE1AR | 1.5001 | DEFEND | DEFEND | 99.63 | NO | 1 |
| | ↓ | " | " | ↓ | " | " |
| | ↓ | " | " | ↓ | " | " |
| 3ARBDE1AR | 1.5001 | DEFEND | DEFEND | 99.53 | NO | 1 |
| | ↓ | " | " | ↓ | " | " |
| | ↓ | " | " | ↓ | " | " |
| HQ2BDE101 | 2 | DEFEND | DEFEND | 99.89 | NO | 1 |
| | ↓ | " | " | ↓ | " | " |
| | ↓ | " | " | ↓ | " | " |

**Table 12. Unit Change List For Dahrahn Air Defense Units.**

that the game controllers did not allow SAM engagements to ensure that the port of Dahrahn sustained damage. This was done in order to perform analysis on the Coalition forces' ability to overcome a successful air strike on their main port of entry into the theater. To alter the scenario in such a manner, Coalition ROE were changed so that air defense units would not engage *any* potential targets.

## F. EVENT THREE: IRANIAN CVBG RAID

The "decision tree" for Critical Event Three, the naval attack, is shown in Figure 18. Since Coalition offensive counter-air operations were not scripted into this scenario, which other factors caused the CVBG to suffer such a devastating blow at the hands of the Iranian air and naval forces? Was it due to poor intelligence, lack of defensive capability, or to a supply or equipment shortfall? Offensive counter-air

**Was the success of the Iranian CVBG raid due to poor Coalition air defense? Which CVBG units had air defense capabilities? What was the status of all their air defense assets?** The Carrier Battle Group, comprised of Aegis cruisers, destroyers and frigates amassed a formidable air defense capability. At the start of the exercise, all units were at full strength and full supply compliment. The CVBG was on alert along a threat sector which included the likely avenues of approach from Busher, Shiraz, Esfahan and Kharg Island. The three CAP stations were active, and the entire carrier air wing was at its highest state of readiness.

**Report status of CVBG air search radars**. All units' air search radars were operational with no reported deficiencies.

**Was poor intelligence a factor in the success of the Iranian CVBG raid? Report if a change in threat perception occurred from initial classification.** At the commencement of the exercise, the Iranians were already declared "hostile". The locations of the air bases at Busher and Shiraz were known, as were the locations of naval and SAM assets in the Iranian arsenal.

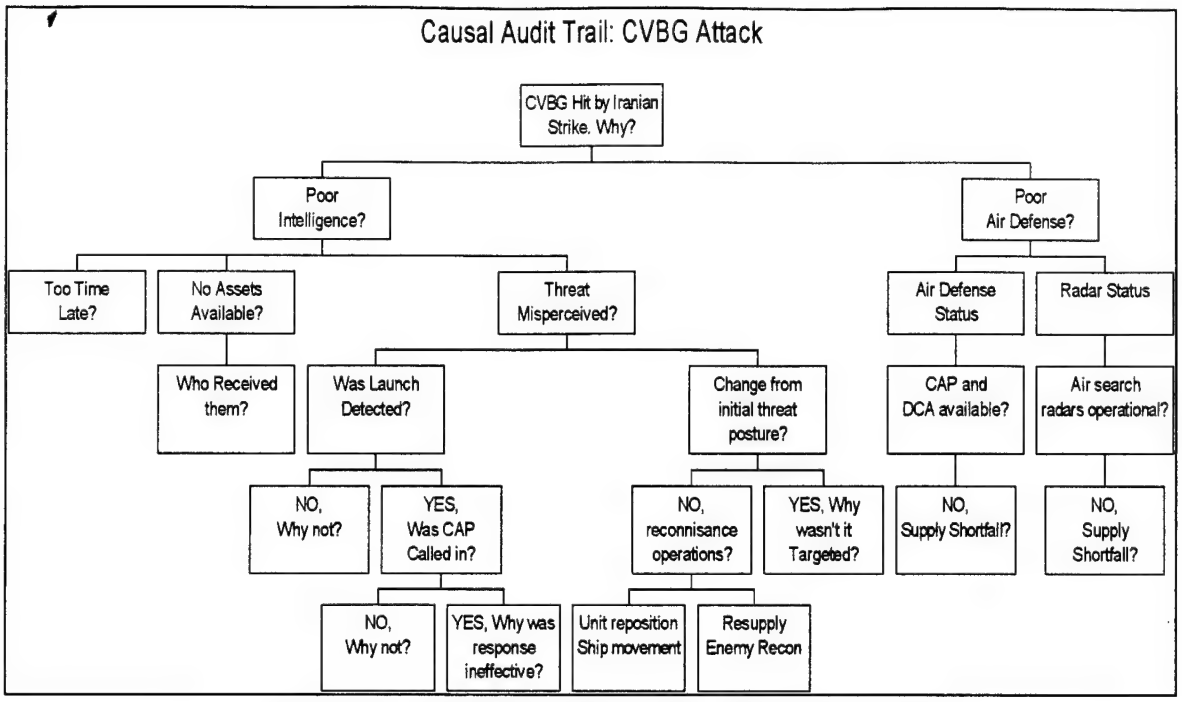



**Figure 18. Event 3 causal audit trail decision tree.**

**Report all organic intelligence data regarding Iranian forces forwarded during period of inquiry.** The given scenario as implemented did not employ the available intelligence collection capabilities. Had the ability to deploy and receive data from intelligence assets been used in this scenario, the following queries could have been made:

- Reports of the tasking of all Coalition air recce, ELINT, and HUMINT assets at the time of the attack.
- Reports of all air recce intelligence, ELINT, and HUMINT data forwarded during the given period leading up to the Iranian CVBG raid, with comparisons with the actual times of events to determine the time lateness of the data.
- Reports indicating if *any* intelligence regarding the launch of the Iranian strike aircraft was forwarded.

- Reports indicating if *any* intelligence regarding the location or movement of Iranian naval forces was forwarded.
- Reports indicating if resupply, refueling or force buildup was reported by Coalition reconnaissance missions.
- Reports indicating if any Iranian reconnaissance missions were flown from the air bases.

Information available to the analyst can be combined into engagement reports. These reports enable the analyst to "see" the following: the time of engagement, the type of weapon fired, who is firing and who is being fired upon. Reports can be further subdivided to concentrate on air-to-air, surface-to-surface or air defense pictures. From such a collection of data, the frequency and range of fire, destruction of platforms and the tactics of both sides can be inferred.

Table 13 depicts a section of the SURFACE-TO-SURFACE ENGAGEMENT REPORT. Engagements are sequential and take place in a period of less than three hours. Conflict is initiated by Iranian surface vessels. The attack destroys two of the three CAP stations. Repeated waves of aircraft from Busher and Shiraz coordinate their missile launches so that the arrival of Anti-Ship Cruise Missiles (ASCMs) is simultaneous with the arrival of shore based missiles, which are successful in not only disabling the carrier, but also completely destroying both cruisers.

| Firer | Engagement | Weapon | Successful impacts | Target |
|---|---|---|---|---|
| PATRON | AIR_MISSION | HARPOON | 7 | CVN-71 |
| DD-IRAN | MISSILE | SS-N-22 | 1 | CG-69 |
| CG-IRAN | MISSILE | SS-N-19 | 1 | CG-53 |
| CG-IRAN | MISSILE | SS-N-19 | 1 | CG-53 |
| FITRON. | AIR_MISSION | ROCKETS | 76 | CVN-71 |
| CG-IRAN | MISSILE | SS-N-19 | 1 | CVN-71 |
| CG-IRAN | MISSILE | SS-N-19 | 1 | CVN-71 |
| KHARG | MISSILE | SS-N-22 | 1 | CG-53 |
| BUSHER. | MISSILE | SCUD | 1 | AOR-7 |
| BUSHER. | MISSILE | SCUD | 1 | FFG-38 |
| FARON1. | AIR_MISSION | AS4 | 4 | CVN-71 |
| FARON2. | AIR_MISSION | HARPOON | 2 | CG-69 |
| HAKRON | AIR_MISSION | AS4 | 2 | CG-69 |
| FARON2. | AIR_MISSION | HARPOON | 1 | CVN-71 |
| FARON1. | AIR_MISSION | AS4 | 4 | CG-53 |
| CG-IRAN | MISSILE | SS-N-19 | 1 | CG-53 |
| CG-IRAN | MISSILE | SS-N-19 | 1 | CVN-71 |
| KHARG | MISSILE | SS-N-22 | 1 | CG-53 |
| BUSHER. | MISSILE | SCUD | 1 | AOR-7 |
| BUSHER. | MISSILE | SCUD | 1 | AE-29 |

**Table 13. Surface to Surface Engagement Report.**

Figure 19 provides a snapshot of the coordinated enemy air assets attacking the CVBG. Damage to the carrier significantly hinders the ability to launch and recover aircraft, thereby removing medium and long range AAW. Without CAP and defensive counter air (DCA), the destruction of the cruisers was imminent. Land-based air forces (both USMC and USAF) were available, but not used in this scenario. This, like other artificialities, was part of the experimental design. Each cruiser was able to sustain an initial wave of missile and aircraft attacks with moderate damage but could not defend against subsequent raids after sustaining initial damage. Though the simulation ends at this point, it is safe to assume that the remaining non-AAW assets would soon fall prey to the attacking missile forces if the scenario were continued.

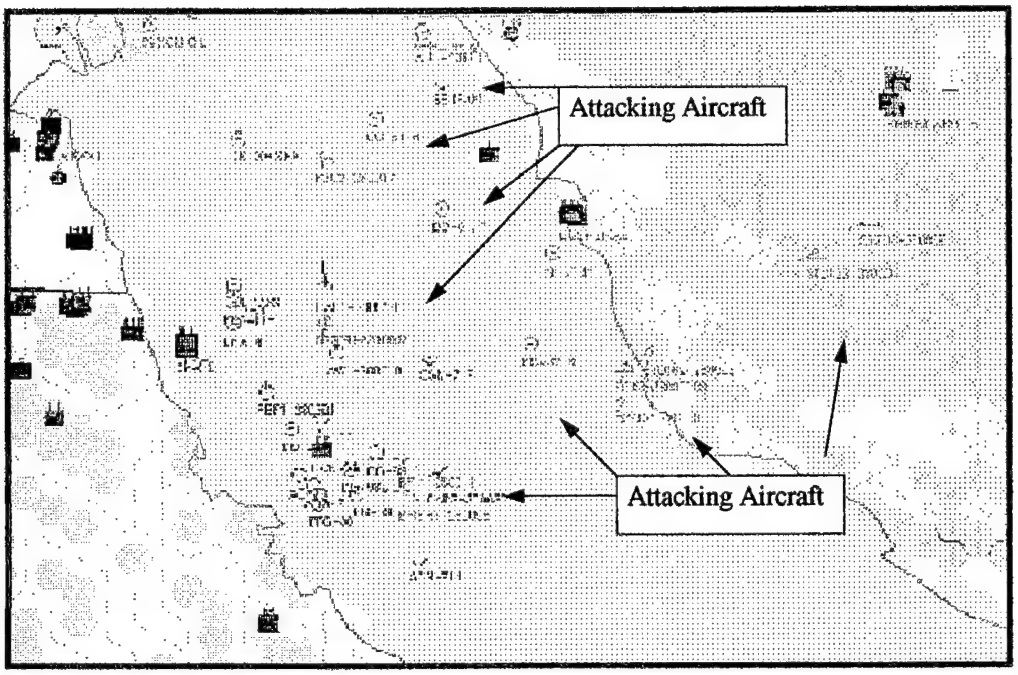



**Figure 19. Scenario Action, Critical Events 3 and 3(A).**

While the previous analysis focused primarily on the CVBG engagement data, there are many more parameters available for the study in the AAW performance of a battle group. The product of each unit's strength and the unit's AAW capability factor yields the battle group's cumulative AAW strength as a function of time. The AAW strength factors used for the analysis in this thesis are provided in Appendix B. Though not a stand-alone measure for AAW performance, the AAW strength can provide the causal audit trail of events leading to the destruction of the CVBG. For example, should a primary AAW asset be completely destroyed, the overall AAW capability of the battle group will be severely diminished and the subsequent destruction of additional assets would be more likely.

The AAW strength of the CVBG initial index value is the sum of all products of CVBG assets and their AAW strength factor. Figure 20 provides the strength measures over time.

Initial degradation is a result of the initiation of conflict, during which the Iranian surface patrol craft shot down the CAP aircraft. The carrier was subjected to only two waves of missile attacks, with the second wave providing the final destructive blow. With the destruction of the carrier also comes the removal of her air wing, most of which were able to fly off prior to the sinking of the ship. Regardless, the wing was now unable to provide sufficient CAP or DCA aircraft during the height of the attack, thereby weakening the overall CVBG strength proportionally. With the loss of the carrier and the cruisers, eighty per cent of the total AAW capability of the CVBG was lost.

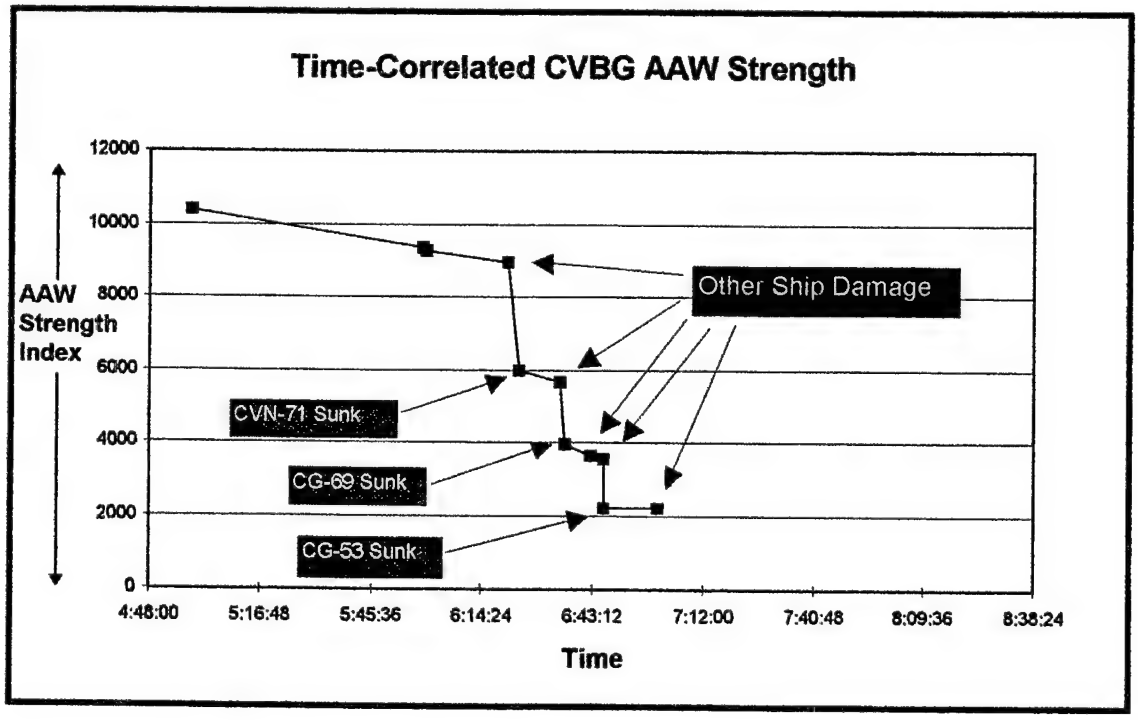



**Figure 20. Time-Correlated AAW Strength Measure.**

Only fourteen percent of Iranian aircraft were destroyed, while only twenty five percent of Iranian missiles were intercepted by the CVBG, but why? Supply shortages do not appear to be linked to the devastating blow to the CVBG. The lack of Coalition intelligence gathering capabilities could have been a contributing factor. It was the sheer number of enemy units, both air and missile threats, combined with lack of availability of Coalition air assets, that were the primary factors in causing the swift degradation of the CVBG's ability to fight.

The degradation of CAP aircraft and the destruction of CG assets decreased the number of Iranian aircraft engagements. Concentration of resources then shifted from air engagements to missile engagements. Figure 21 provides a graphical representation of the CVBG's ability to execute defense-in-depth. Defense-in-depth provides for engagements by long range weapons (CAP aircraft) initially, followed by medium range weapons (Surface-to-Air Missile (SAMs)), then by short range weapons (Basic Point Defense Missile System (BPDMS)) and finally the Phalanx Close-In-Weapon Systems (CIWS) to cover the entire range of the flight profile to a High Value Unit (HVU). This layered defense approach provides the maximum number of potential weapons on the threat during the course of its flight, maximizes the overall kill probability and reduces the likelihood of the enemy countering all defensive systems with a single weapon system. Ideally, the enemy aircraft will be destroyed at the minimum of either the identification or effective weapons range.

All engagements in this case are SAM engagements, due to the initial loss of the CAP aircraft. The greatest value of this graph is that of determining, due to the

scarcity of aircraft engagements, that a concentration of effort was expended *not* on engaging aircraft, but instead on engaging missiles. This serves as an immediate flag to

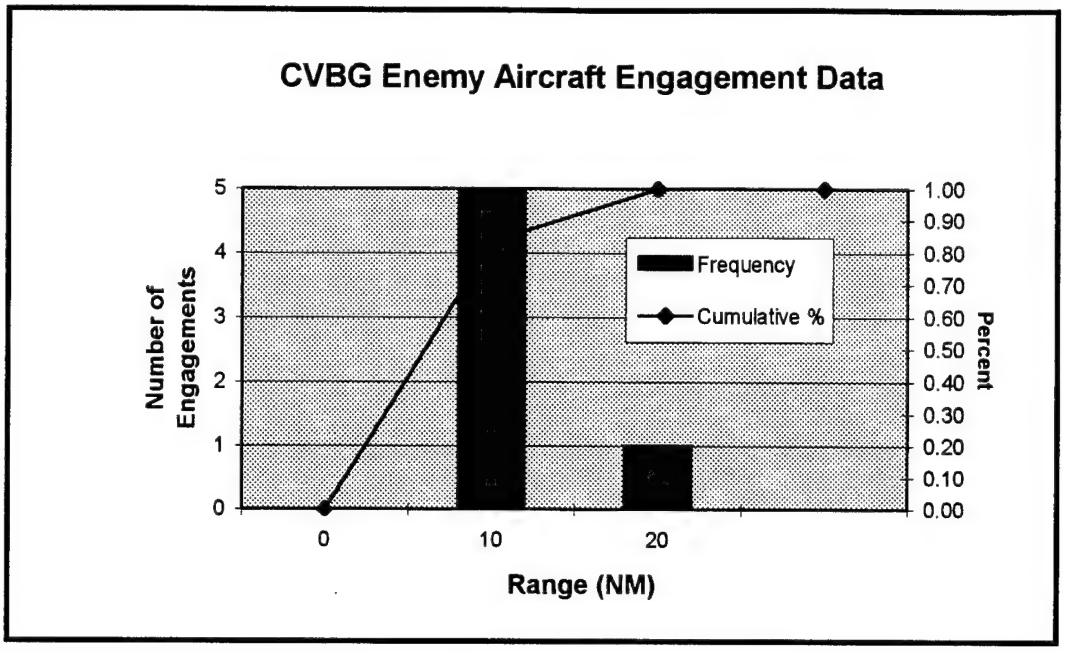



**Figure 21. CVBG Enemy Aircraft Engagement.**

the breakdown of the defense-in-depth concept because the number of aircraft engagements, given the magnitude of the total number of incoming aircraft in this scenario, should be significant. The CVBG loss of CAP and reduction in DCA resulted in a change in tactics from destruction of the "archer" to the more difficult destruction of the "arrows."

## G. EVENT THREE (A): CVBG RAID, IRANIAN PERSPECTIVE

Analysis of Event Three from the threat perspective answers the question of how the Iranians were able to locate the Coalition CVBG. Figure 22 shows the causal audit

trail decision tree for Critical Event Three (A), the Iranian raid on the Coalition CVBG, from the Iranian perspective.

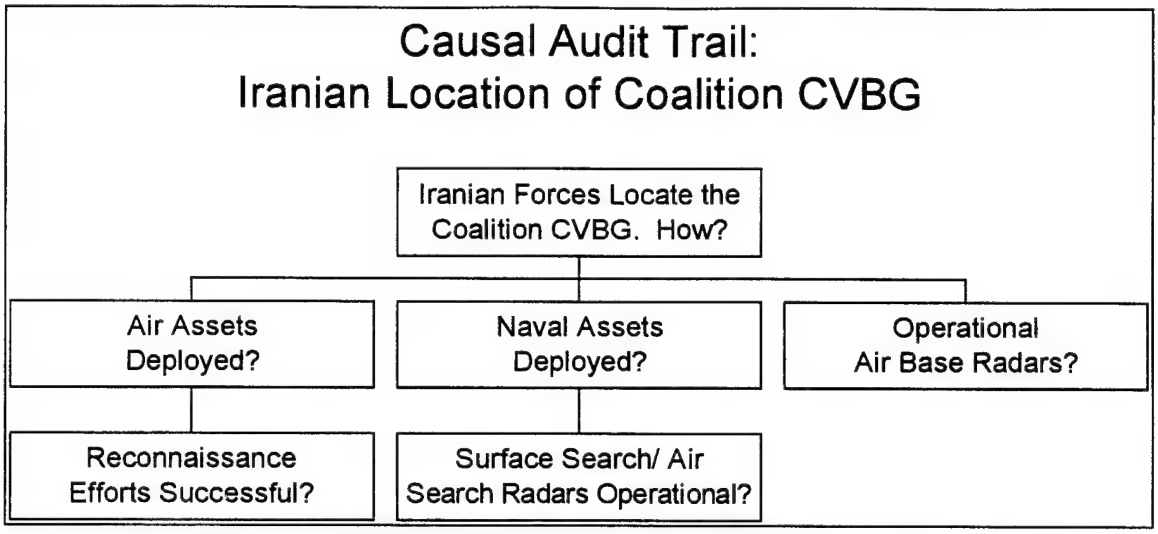



**Figure 22. Causal Audit Trail Decision Tree for Critical Event 3(a).**

**Were the radars at the Iranian air bases of Esfahan and Shiraz fully operational at the time of detection of the Coalition CVBG?** Shiraz and Esfahan were not equipped with *surface* search radars, but their *air* search radars were fully operational. At no time during the scenario did either of these radars provide initial detection information dealing with any Coalition air tracks.

**Were Iranian naval assets deployed to assist in locating the Coalition CVBG?** An Iranian cruiser and destroyer, both with operational air and surface search radars, were steaming in the Persian Gulf region, but they were not the initial sources of detection of any Coalition air or surface tracks.

**Were Iranian air assets deployed to assist in locating the Coalition CVBG?** The Iranian air forces were thoroughly patrolling the entire gulf region. The number of

Iranian detections of Coalition naval units shows that the CVBG's location was clearly known to the Iranian forces early in the scenario.

The sources of the Iranian detections of Coalition naval units are, in this case, limited to Iranian reconnaissance and armed reconnaissance aircraft (Table 14) due to the

| Scenario Time | Unit Detected | Detecting Side | | Scenario Time | Unit Detected | Detecting Side |
|---|---|---|---|---|---|---|
| 0.01 | FFG-59 | IRAN | | 0.02 | FFG-38 | IRAN |
| 0.01 | AE-29 | IRAN | | 0.03 | AOR-7 | IRAN |
| 0.01 | CVN-71 | IRAN | | 0.04 | VA-36 | IRAN |
| 0.01 | DD-966 | IRAN | | 0.04 | VF-84 | IRAN |
| 0.01 | CG-53 | IRAN | | 0.05 | SSN-717 | IRAN |
| 0.02 | SSN-714 | IRAN | | 0.08 | DD-982 | IRAN |
| 0.02 | VF-154 | IRAN | | 0.08 | VFA-195 | IRAN |

**Table 14. Summary of Iranian Patrol Detections of Coalition Units.**

detection algorithms inherent in JTLS. The first sensor to detect a given unit within a hex is registered as the "detecting unit" regardless of subsequent detections by other units. This explains the lack of detections attributed to the Iranian land-based and naval assets.

The scenarios discussed in this chapter were constrained to facilitate UJTL analysis across several functional areas. The methodology presented in this thesis was later applied to less constrained JTLS runs described in Chapter V. These runs provide a more realistic basis for applying the audit trail methodology.

# V. RESULTS OF JTLS 2.1 DEMONSTRATION SCENARIO

## A. SCENARIO BACKGROUND

The basic scenario used for the JTLS 2.1 demonstration is nearly identical to the variants of the heavy scenario described in Chapter III. The force composition of both sides and the initial "script" of the scenarios were similar, but the execution of the wargame differed in the following ways:

- Coalition air forces were utilized to the fullest possible extent.
- Coalition forces were heavily involved in intelligence operations.
- Scenario ROE were configured such that Coalition forces would be allowed to conduct air defense operations.
- The outcome of the wargame was heavily dependent on the players. The leadership of the Coalition forces was made up of a collection of fifteen junior military officers (novice gamers with aggressive tactics) who participated in the exercise as a requirement for a graduate level wargaming course at the Naval Postgraduate School.
- Game controllers were R&A personnel, who also doubled as the Iraqi and Iranian military leadership.

As could be predicted, the combination of these factors led to drastically different results. The runs discussed in Chapters III and IV (hereafter referred to as the UJTL scenario) were very controlled scenarios designed to produce results suitable for analysis of specific UJTL mission areas. The JTLS 2.1 scenario wargame was played in a free play mode to

meet the objective of familiarizing junior officers with wargaming principles and JTLS. Accordingly, students operated with few restrictions placed on their playing styles and tactics. However, the same analysis methodology can still be applied.

## B. CRITICAL EVENT SELECTION

To demonstrate the differences in the outcomes of the JTLS 2.1 and UJTL scenarios, corresponding "parallel" critical events are analyzed in later sections.

Critical Event One (B) is a variation of Critical Event One discussed in Chapters III and IV. The Madinah Division was not allowed to accomplish an unimpeded withdrawal in this scenario. The Madinah, along with three accompanying Iraqi units, is surrounded and defeated by a larger coalition contingent of ground forces (Figures 23 and 24). **Why were the coalition forces able to track down and annihilate the Madinah Division and its accompanying Iraqi forces?**

Critical Event Two (B) is a variation of Critical Event Two discussed in Chapters III and IV. The port of Dahrahn fell victim to Iraqi air strikes in the UJTL scenario, causing lengthy delays of forces and supplies entering the theater. The air strike in the JTLS 2.1 scenario also resulted in damage to the port, but Coalition air defense and Coalition air forces *were* active in the JTLS 2.1 scenario. **Why was the Iraqi air strike on the Port of Dahrahn successful?**

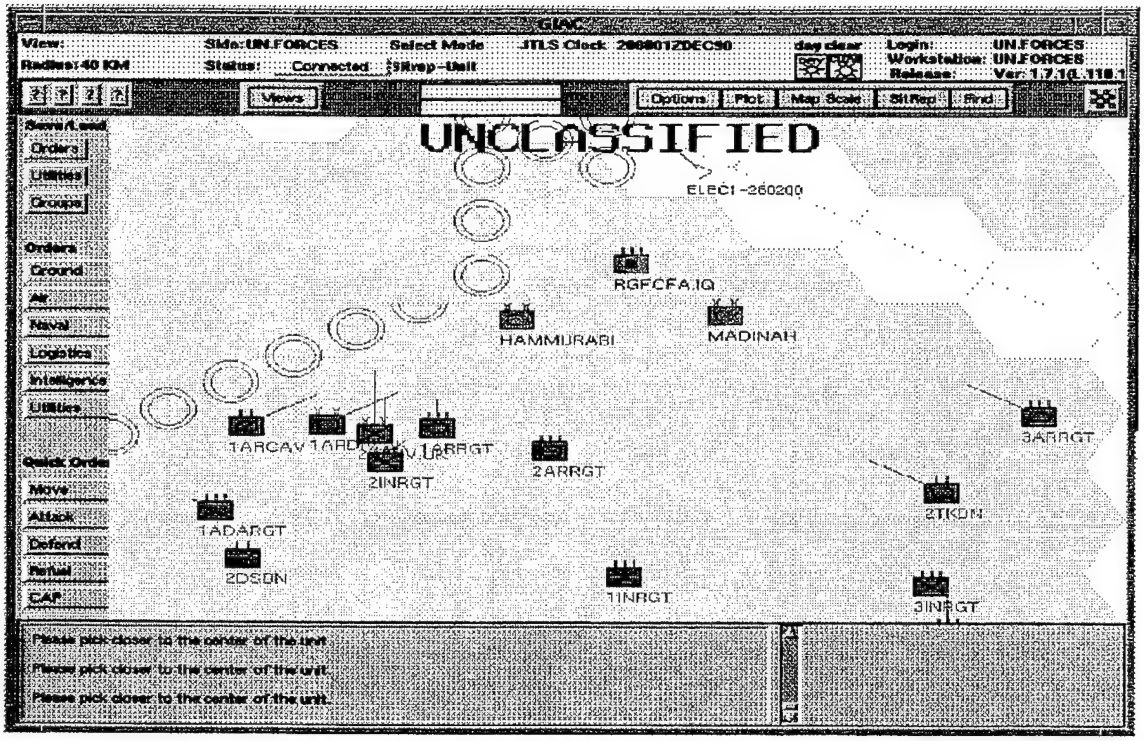



**Figure 23. Force Locations at time 0.334.**

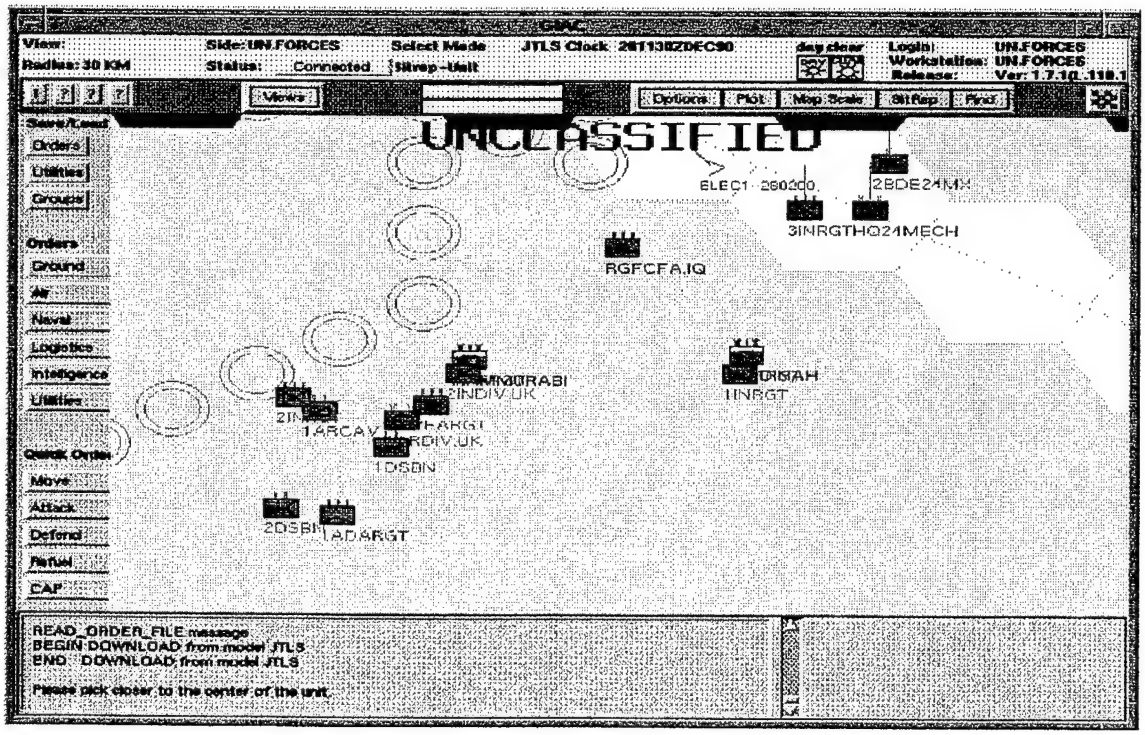



**Figure 24. Force Locations at time 0.479.**

## C. ANALYSIS OF CRITICAL EVENT ONE (B): THE MADINAH DEFEAT

The downfall of the Madinah Division is clearly evident in their unit change list (Table 15). The Madinah is quickly overrun by a flurry of Coalition forces during a lopsided battle.

| Time | Detecting Source | Perceived Posture | Perceived Strength | Perceived Lat | Perceived Long | Actual Lat | Actual Long |
|---|---|---|---|---|---|---|---|
| 0.063 | COMBAT | DEFEND | 99.472 | 28.25 | 46.283 | 28.25 | 46.28 |
| 0.375 | COMBAT | DEFEND | 99.079 | 28.25 | 46.283 | 28.25 | 46.28 |
| **0.417** | **COMBAT** | **DEFEND** | **84.922** | **28.25** | **46.283** | **28.25** | **46.28** |
| 0.458 | COMBAT | WITHDRAW | 77.474 | 28.25 | 46.283 | 28.25 | 46.28 |
| 0.500 | COMBAT | WITHDRAW | 63.774 | 28.25 | 46.283 | 28.25 | 46.28 |
| 0.542 | COMBAT | WITHDRAW | 59.813 | 28.25 | 46.283 | 28.25 | 46.28 |
| 0.583 | COMBAT | WITHDRAW | 56.588 | 28.25 | 46.283 | 28.25 | 46.28 |
| 0.625 | COMBAT | WITHDRAW | 53.73 | 28.25 | 46.283 | 28.25 | 46.28 |
| 0.667 | COMBAT | WITHDRAW | 51.000 | 28.25 | 46.283 | 28.25 | 46.28 |
| 0.708 | COMBAT | WITHDRAW | 48.335 | 28.25 | 46.283 | 28.25 | 46.28 |
| 0.750 | COMBAT | WITHDRAW | 46.022 | 28.25 | 46.283 | 28.25 | 46.28 |
| 0.792 | COMBAT | WITHDRAW | 43.859 | 28.25 | 46.283 | 28.25 | 46.28 |
| 0.833 | COMBAT | WITHDRAW | 41.735 | 28.25 | 46.283 | 28.25 | 46.28 |
| 0.875 | COMBAT | WITHDRAW | 39.651 | 28.25 | 46.283 | 28.25 | 46.28 |
| 0.917 | COMBAT | WITHDRAW | 37.137 | 28.25 | 46.283 | 28.25 | 46.28 |
| 0.958 | COMBAT | WITHDRAW | 34.101 | 28.25 | 46.283 | 28.25 | 46.28 |
| 1.000 | COMBAT | WITHDRAW | 31.087 | 28.25 | 46.283 | 28.25 | 46.28 |
| 1.020 | COMBAT | WITHDRAW | 31.087 | 28.25 | 46.283 | 28.25 | 46.28 |
| 1.040 | COMBAT | WITHDRAW | 28.213 | 28.25 | 46.283 | 28.25 | 46.28 |
| 1.080 | COMBAT | WITHDRAW | 22.997 | 28.25 | 46.283 | 28.25 | 46.28 |
| 1.130 | COMBAT | WITHDRAW | 20.506 | 28.25 | 46.283 | 28.25 | 46.28 |
| 1.170 | COMBAT | INCAPABLE | 18.117 | 28.25 | 46.283 | 28.25 | 46.28 |
| 1.210 | COMBAT | INCAPABLE | 15.837 | 28.25 | 46.283 | 28.25 | 46.28 |
| 1.250 | COMBAT | INCAPABLE | 11.172 | 28.25 | 46.283 | 28.25 | 46.28 |

**Table 15. Unit Change List for the Madinah Division.**

The rapidly declining force strength can also be seen in Figure 25. At time 0.417, the Madinah is hit with the initial surge of Coalition fire. The causal audit trail decision

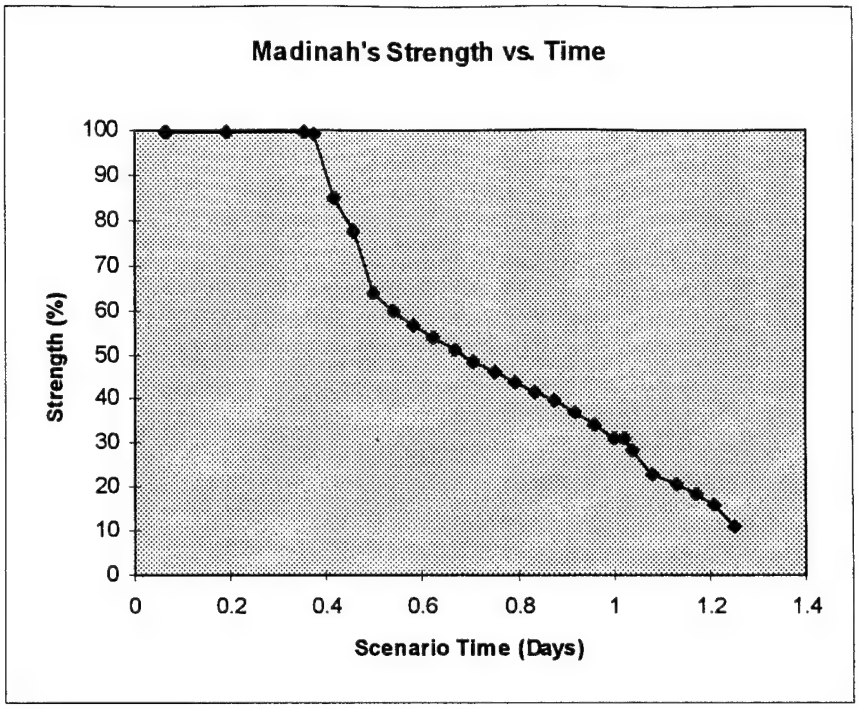



**Figure 25. Madinah's Strength vs. Time**

tree for Critical Event One (B) is shown in Figure 26.

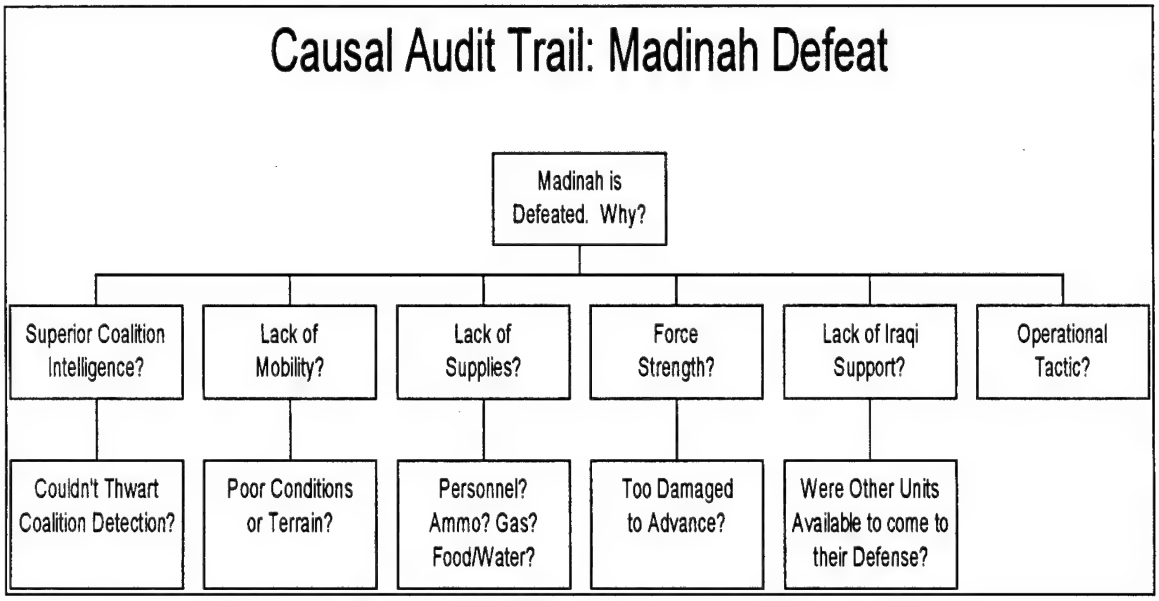



**Figure 26. Event One (B) causal audit trail decision tree.**

**Was the Madinah Division defeated due to a superior Coalition intelligence effort?** The answer to this question is evident in Table 15, which shows that Madinah's

location and the Coalition perception of their location were *identical* throughout the entire scenario. The Madinah's proximity to Coalition ground forces did not allow it to avoid detection by Coalition forces.

**Was the Madinah defeated due to a lack of Iraqi support?** Considering the force composition of both sides at the beginning of Madinah's defeat at time 0.417 (Table 16), it is clearly evident that the Iraqi contingent was outnumbered and outgunned. This is

| IRAQI UNITS | DISTANCE (MILES) FROM MADINAH | IN COMBAT? | COALITION UNITS | DISTANCE (MILES) FROM MADINAH | IN COMBAT? |
|---|---|---|---|---|---|
| 17ARDIV | 28.267 | YES | 1ARCAV | 21.496 | YES |
| HAMMURABI | 13.252 | YES | 1ARDIV.UK | 16.973 | YES |
| RGFCFA.IQ | 7.348 | YES | 1ARRGT | 15.986 | YES |
| | | | 1FARGT | 16.532 | YES |
| | | | 1INRGT | 0.536 | YES |
| | | | **2ARRGT** | **0.000** | **YES** |
| | | | 2BDE24MX | 21.794 | YES |
| | | | 2FARGT | 15.370 | YES |
| | | | 2INDIV.UK | 13.537 | YES |
| | | | 2INRGT | 21.747 | YES |
| | | | 2TKBN | 20.275 | YES |
| | | | 3ARRGT | 19.310 | YES |
| | | | 3INRGT | 13.615 | YES |

**Table 16. Units in vicinity of Madinah at time 0.417.**

a result of the aggressive tactics used by wargaming personnel. Their decisions affecting the positioning and posturing of the Coalition forces resulted in total defeat of the Iraqi forces due the velocity and quantity of forces sent to oppose them.

**Was Madinah defeated due to an Iraqi or Coalition operational tactic?** This question was answered in the previous paragraph. The positioning and posturing of the coalition forces due to player interaction were key elements in the Iraqi forces' defeat.

What caused players to make these tactical decisions? These actions were due to a combination of

- The accurate location information of the Iraqi forces available to Coalition leaders.
- Various human factors that influenced the tactical decision process.

**Was the Madinah defeated due to a lack of mobility or a lack of supplies?** A review of the Madinah Division supply category change list revealed that no supplies were significantly depleted during the period leading up to the beginning of Madinah's defeat. Madinah's mobility was not constrained by terrain or environmental effects.

The causal audit trail revealed the Madinah Division's defeat was caused by a combination of 1) superior Coalition intelligence dealing with the Madinah Division location and 2) the aggressive operational tactics input through player interaction.

## D. ANALYSIS OF CRITICAL EVENT TWO (B): THE DAHRAHN AIR STRIKE

Figure 27 depicts the causal audit trail decision tree for Critical Event Two (B), the Dahrahn Air Strike.

**Was the air strike on the port of Dahrahn successful due to poor Coalition Air Defense?** In this scenario, Coalition ROE were configured so that air defense engagements of Iraqi units could happen, and they did. However, of the eight aircraft in the four missions that flew air to ground attacks against targets in the port of Dahrahn,

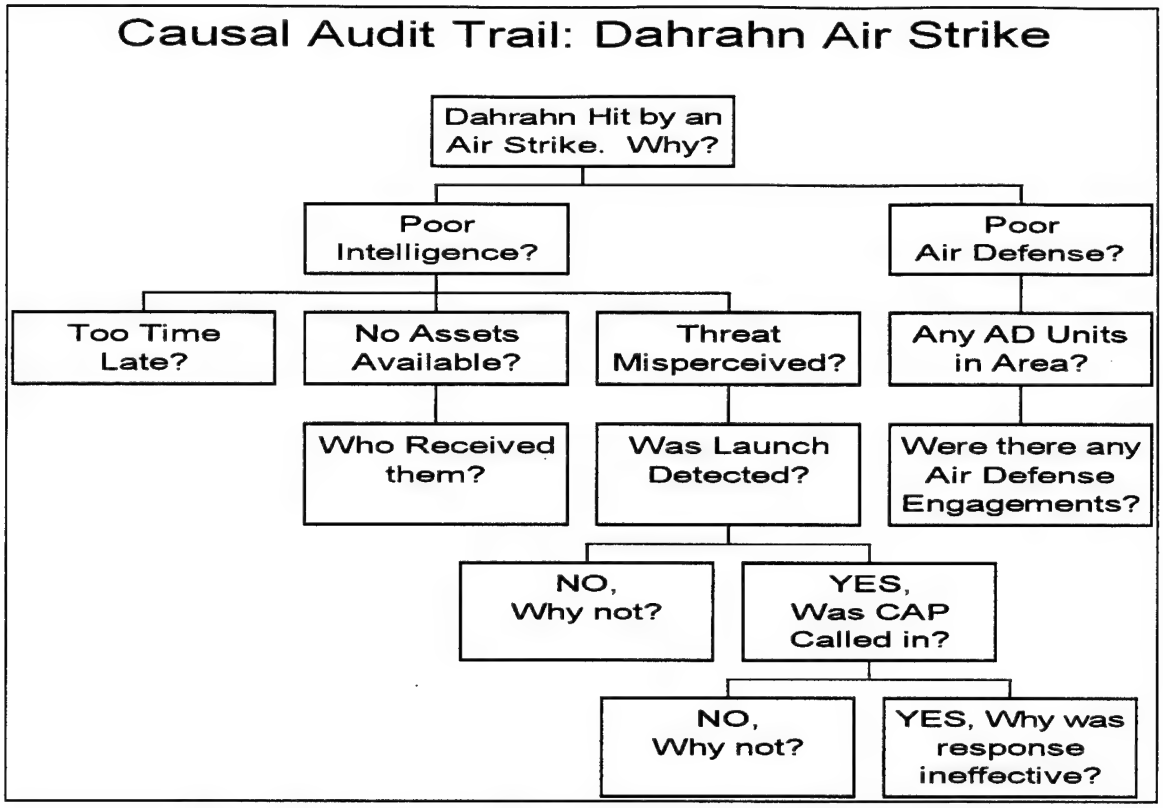



**Figure 27. Event Two (B) Causal Audit Trail Decision Tree.**

only one was shot down by Coalition air defense units (Tables 17 and 18).

Why was only *one* shot down? The audit trail prompts the analyst to next consider how many air defense units were in the area to determine why more air defense engagements did not take place. Using the methodology from Chapter IV, the coalition

| Time | Mission # | Type | Home Squadron | # A/C | A/C Type | Dest Lat | Dest Long |
|---|---|---|---|---|---|---|---|
| 0.250 | DHA-1 | ATTACK | 1AVN.RGT | 2 | MIG27-D | 26.40 | 50.02 |
| **0.250** | **DHA-2** | **ATTACK** | **1AVN.RGT** | **2** | **MIG27-D** | **26.40** | **50.02** |
| 0.563 | DHA-3 | ATTACK | 1AVN.RGT | 2 | MIG27-D | 26.40 | 50.02 |
| 0.563 | DHA-4 | ATTACK | 1AVN.RGT | 2 | MIG27-D | 26.40 | 50.02 |

**Table 17. Summary of Iraqi Attack Missions against the Port of Dahrahn.**

| Time | Firing Site | Weapon Fired | # Fired | Target Mission # | # Kills | Engage Range (KM) |
|---|---|---|---|---|---|---|
| 0.542 | HAWK-SA8 | HAWK | 2 | DHA-2 | 1 | 17.02 |

**Table 18. Summary of Coalition Air Defense Engagements.**

air defense units in a 100 by 100 mile box surrounding Dahrahn are shown in Table 19. In this scenario, these units are not players in Dahrahn's air defense because they are all located nearly 60 miles to the northwest. The port of Dahrahn is represented by the unit

| Unit Name | Air Defense Assets |
|---|---|
| 1-2ADABN | 2 Stingers with 11 Firing elements each |
| 3-2ADABN | 2 Stingers with 11 Firing elements each |
| 1ARBDE1AR | 1 Patriot battery with 6 Firing elements |
| 2ARBDE1AR | 1 Patriot battery with 6 Firing elements |
| 3ARBDE1AR | 1 Patriot battery with 6 Firing elements |
| HQ1BDE101 | 2 Stingers with 11 Firing elements each |
| HQ2BDE101 | 2 Stingers with 11 Firing elements each |
| HQ3BDE101 | 2 Stingers with 11 Firing elements each |

**Table 19. Air Defense Units near Dahrahn.**

DHARPORT in JTLS. DHARPORT is a Coalition unit with two Hawk sites under its control, HAWK-SA7 west of Dahrahn and HAWK-SA8 in Dahrahn. Table 20 describes the capabilities of a Hawk missile site in this JTLS scenario. A Hawk site is limited in range to a *best case* maximum of 40 KM. Given that the attacks on Dahrahn came in two waves of four planes each, it is a reasonable outcome for only one air defense engagement to occur. The HAWK-SA8 site shot two missiles at the first wave of Iraqi aircraft: missions DHA-1 and DHA-2. One of the four aircraft was shot down, one missile missed, and the site was suppressed for the remainder of the attack. The second wave of aircraft, missions DHA-3 and DHA-4, were not detected by either Hawk site.

- **Was the port of Dahrahn hit due to a lack of intelligence?** A review of Coalition intelligence reports shows that Coalition forces were never alerted when any of the four attack missions against Dahrahn were launched. Consideration of the intelligence assets utilized by the Coalition leadership shows a strong concentration of air forces near KKMC, but none near Dahrahn. Due to the inexperience of the players with the mechanics of creating CAP stations, they were not activated until early on Day Two, well after the Dahrahn air strike. This delay resulted in a lack of assets to perform air-to-air engagements on the incoming Dahrahn air strike missions. Analysis of the scenario's air-to-air engagement table confirms that there were many Iraqi missions targeted by Coalition air forces, but none of them were the missions headed for Dahrahn.

| **Maximum Engagement Ranges:** | |
|---|---|
| **Altitude Ranges (ft)** | **Range of Site(KM)** |
| 0 - 500 | 5 |
| 500 - 10000 | 20 |
| 10000 - 25000 | 40 |
| 25000 - 50000 | 20 |
| 50000 - 100000 | 10 |
| | |
| **A/C Type Engagement Probabilities:** | |
| **A/C Target Type** | **Probability of Engagement** |
| Bomber | 0.45 |
| Fighter | 0.35 |
| Helo | 0.40 |
| | |
| **Misc. Air Defense Characteristics:** | |
| Number of Simultaneous Engagements | 2 |
| Suppression Time | 0.499 Hours |
| Reload Time | 0.5 Hours |
| Total Shots | 18 |
| Shots per Load | 9 |
| Shots per Engagement | 2 |
| Shots before Reload | 9 |

**Table 20. Air Defense Characteristics of a Hawk Site.**

In summary, the causal audit trail revealed that the Dahrahn air strike was successful for the following reasons:

- The limited number and capabilities of Dahrahn's organic air defense sites.
- A lack of Coalition CAP assets in the vicinity of the Dahrahn, primarily due to a lack of player experience. Note that this is one case where player actions (or interactions) are directly observable for audit trail analysis.

# VI. CONCLUSIONS AND RECOMMENDATIONS

"Out of intense complexities, intense simplicities emerge." - Winston Churchill

## A. CONCLUSIONS

This thesis presents a methodology for specifying and evaluating the causal factors defining computer aided exercise critical events. The methodology developed is uncomplicated, yet robust enough to be applicable to a variety of warfare areas, regardless of scenario. The methodology is comprised of two significant elements. The first is the identification of a scenario's *potential* critical events and the determination of their *possible* causes at many different "levels of influence." The second is the development of the data extraction procedures necessary for manipulation of raw output into user-friendly, objective tables.

The methodology does not seek to assign values to each individual joint task stated in the UJTL, but instead determines how the outcomes of significant events were impacted by the mix of forces present in theater and their location relative to the enemy at the time the events took place. Although tested exclusively in JTLS, the methodology uses data readily accessible from other event step simulation models.

An important limitation to such analysis is that each simulation represents one possible outcome based upon randomness introduced both by the stochastic simulation and human interactions. Every player has some sort of decision making process that is evoked before actions are taken. The same is true for participants in a CAX. Every time a decision is made, a player analyzes competing alternatives *and chooses the one he deems*

*most appropriate*. Due to the artificialities inherent in the exercise environment, CAXs cannot be the only measure of the capabilities of a CINC's staff, even though they provide valuable data and training,

## B. RECOMMENDATIONS

This thesis must be viewed as part of the overall effort to assist in evaluating the performance of a Joint Staff. Along with the theses mentioned in Chapter II, this thesis provides the baseline for future efforts to develop a standard methodology for evaluating Joint Staff performance. Standardized methods for evaluating the decision making process of a Joint Staff will provide a causal audit trail for success or failure and further enrich the training benefits available to a Joint Staff during a CAX.

At present, to create the causal audit trail described in this thesis, the analyst must first access the critical event. Next, he or she must assemble simulation files, sort them and extract necessary data. Finally, the analyst must create the necessary tables to perform analysis. Involvement of the training audience (that will ultimately be the beneficiary of this methodology) at all steps of the process is essential.

For example, if a wargame is being run to focus on a staff's performance regarding logistics, several pre-made checklists and decision trees could be available (perhaps in a window driven, pull-down menu environment) and ready for analysis of logistics specific potential critical events. These accessories could be available for any potential mission area on which a wargame intends to focus. Automation of this function will also allow for

time which would otherwise be spent developing the mechanics of the causal audit trail to be devoted to more in-depth analysis.

Another potential application of the developed methodology is that it could be employed as a training tool or decision aid during the actual exercise. Once technology is developed to analyze trends in a scenario and view the causes of critical events *while the scenario is being played,* the performance of wargaming personnel should be significantly enhanced.

The query/analysis capabilities that have been introduced support the development of doctrine evaluation. As the pieces of the audit trail are revealed, the analyst is able to recreate the events which led to a critical event. The ability to rerun the scenario in JTLS with minor changes to the event/causal item(s) could open avenues for the evaluation of tactics and doctrine.

# APPENDIX A. JTLS 2.0 JMET OUTPUT FILE CONTENT

The following is a list of the availiable JTLS 2.0 JMET output files and their associated data elements:

**air_mission_data:**

TIME.V
AM.NAME(THE.MISSION)
FS.NAME(AM.FORCE.SIDE(THE.MISSION))
MT.NAME(AM.MISSION.TYPE(THE.MISSION))
UT.SHORT.NAME(AM.HOME.SQUADRON(THE.MISSION))
CURRENT.NUMBER.AIRCRAFT
AC.NAME(AM.AIRCRAFT.TYPE(THE.MISSION))
AIR.MISSION(POSTURE.NAME.ARRAY(AM.POSTURE(THE.MISSION))
ORIGINAL.LOAD.NAME
DEST.ONE.LAT
DEST.ONE.LONG
ATTACK.ENTITY.ONE
AM.PROTECTION.ZONE(THE.MISSION)
DEST.TWO.LAT
DEST.TWO.LONG
ATTACK.ENTITY.TWO

**air_track/mission_detection:**

TIME.V
FS.NAME(THE.SIDE)
THE.MISSION.NAME
THE.SENSOR.NAME
THE.TRACK.NAME
THE.SIDE.NAME

**combat_systems:**

TIME.V
UT.SHORT.NAME(THE.UNIT)
THE.NAME
TEMP.CS(THE.SYSTEM, THE.ATTRIBUTE)

**engagement_data:**

TIME.V
TEXT.TYPE.ENGAGEMENT
SHOOTER.NAME
WEAPON.NAME
NBR.FIRED
TEXT.AIM.POINT
REAL.LAT
REAL.LONG
TEXT.VICTIM.NAME
TEXT.TYPE.OBJECT.DAMAGED
NAME.OBJECT.DAMAGED
AMOUNT.DAMAGED
PROB.KILL
ENGAGEMENT.RANGE

The format for a ground mission's engagement data is given below. The format of the engagement_data file changes with the different types of engagements, i.e. artillery mission, air mission, minefield, etc.

**location_data:**

TEXT.TIME
INTEGER.TYPE
TEXT.NAME
NEW.LAT
NEW.LONG
NEW.ORIENTATION

**posture_data:**

TEXT.TIME
INTEGER.TYPE
TEXT.NAME
NEW.POSTURE
TEXT.MISSION

**strength_data:**

TEXT.TIME
TEXT.NAME
TEXT.CAT
TEXT.ATTRIBUTE
TEXT.REASON
REAL.AMOUNT

**target_intel:**

TIME.V
DETECTION.TIME
FS.NAME(THE.SIDE)
DET.SOURCE(THE.SIDE)
TG.CCF.NUMBER(THE.TARGET)
PERCEIVED.SIDE.NAME
PERCEIVED.FACTION.NAME
PERC.STR.ARRAY(THE.SIDE)*100
PERC.LAT.ARRAY(THE.SIDE)
PERC.LONG.ARRAY(THE.SIDE)
TG.DEC.LAT(THE.TARGET)
TG.DEC.LONG(THE.TARGET)

**unit_intel:**

TIME.V
THE.DETECTION.TIME
FS.NAME(THE.SIDE)
DET.SOURCE(THE.SIDE)
UT.SHORT.NAME(THE.UNIT)
PERCEIVED.SIDE.NAME
PERCEIVED.FACTION.ARRAY(THE.SIDE)
POSTURE.NAME
PERC.STR.ARRAY(THE.SIDE)*100
PERC.LAT.ARRAY(THE.SIDE)
PERC.LONG.ARRAY(THE.SIDE)
UT.DEC.LAT(THE.UNIT)
UT.DEC.LONG(THE.UNIT)
PERC.CS.ARRAY(THE.SIDE)
THE.SYSTEM.NAME

**update_data:**

TIME.V
UD.ENTITY.TYPE.(THE.UPDATE)
THE.DETECTED.OBJECT.NAME
SENSOR.NAME
UD.PROB.DETECT(THE.UPDATE)
UD.DETECTOR.NAME(THE.UPDATE)
UD.TIME.OF.OBSERVATION(THE.UPDATE)

# APPENDIX B. AAW STRENGTH FACTORS FOR CVBG ASSETS

The following matrix represents the AAW strength factors used to calculate the CVBG overall AAW strength index. The strength factor is similar to a firepower score for a specific mission (in this case, AAW) when applied as a product with the individual asset strength value. For this scenario, the aircraft carrier and Aegis cruisers are not only HVUs, but are clearly the most heavily weighted AAW assets. To examine other mission (ASW, ASUW, etc.) strengths over time, similar matrices may be derived and applied in the same manner.

| Asset | AAW Factor |
|---|---|
| AE-29 | 1 |
| AOR-7 | 1 |
| CG-53 | 20 |
| CG-69 | 20 |
| CVN-71 | 40 |
| DD-966 | 1 |
| DD-982 | 1 |
| FFG-38 | 5 |
| FFG-59 | 5 |
| VF-154 | 5 |
| VF-84 | 5 |

# LIST OF REFERENCES


1. National Military Strategy of the United States, Washington, D.C., Feb 1994.

2. Joint Chiefs of Staff, CJCSM 3500.04, Universal Joint Task List, version 2.1, The Pentagon, Washington, D.C., May 1995.

3. Combs, Ray, *A Methodology for Evaluating Execution of Universal Joint Tasks Within The Context of A Computer Aided Exercise*, Master's Thesis, Naval Postgraduate School, Monterey, California, Sep 1995.

4. Towery, Christopher, *A Methodology for Evaluating the Performance of Intelligence Functions During a Computer Aided Exercise*, Master's Thesis, Naval Postgraduate School, Monterey, California, Sep 1995.

5. Brown, Kevin, *A Methodology for Evaluating Operational Maneuver in A Computer Aided Exercise*, Master's Thesis, Naval Postgraduate School, Monterey, California, Sep 1996.

6. Mustin, John, *A Methodology for Evaluating Carrier Battlegroup Anti-Air Warfare Capability In A Computer Aided Exercise*, Master's Thesis, Naval Postgraduate School, Monterey, California, Sep 1996.

7. Cwick, Mark, *Analyzing Amphibious Logistic Capabilities In The Joint Theater Level Simulation (JTLS)*, Master's Thesis, Naval Postgraduate School, Monterey, California, Sep 1996.

8. Sullivan, Mark, *A Methodology for Evaluating a Joint Mobilization Plan Using the Joint Theater Level Simulation (JTLS)*, Master's Thesis, Naval Postgraduate School, Monterey, California, Sep 1996.

9. Thurman, John, *A Methodology for Evaluating Force Protection During A Computer Aided Exercise*, Master's Thesis, Naval Postgraduate School, Monterey, California, Sep 1996.

10. Gordon, Kerry, *A Methodology for Evaluating The Performance of Operational Firepower During A Computer Aided Exercise*, Master's Thesis, Naval Postgraduate School, Monterey, California, Sep 1996.

11. Johnson, Stuart E. and Libicki, Martin C., *Dominant Battlespace Knowledge*, National Defense University, Washington, D.C., Feb 1996.

12. Headquarters, Joint Warfighting Center, D-J-0013-O, *Joint Theater Level Simulation Analyst Guide (JTLS 2.1)*. Fort Monroe, Virginia, Jul 1997.

13. Benson, Kirk, *Modeling Data Encapsulation and a Communication Network for the National Training Center, Fort Erwin, CA.*, Master's Thesis, Naval Postgraduate School, Monterey, California, Sep 1996.

14. Koch, G., and Loney, K., *Oracle: the Complete* Reference, Oracle Press, Berkely, California, 1995.

15. Coleman Research Corporation Final Report, *Training Proficiency Evaluation Support Module*. Huntsville, Alabama, Jan 1997.

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